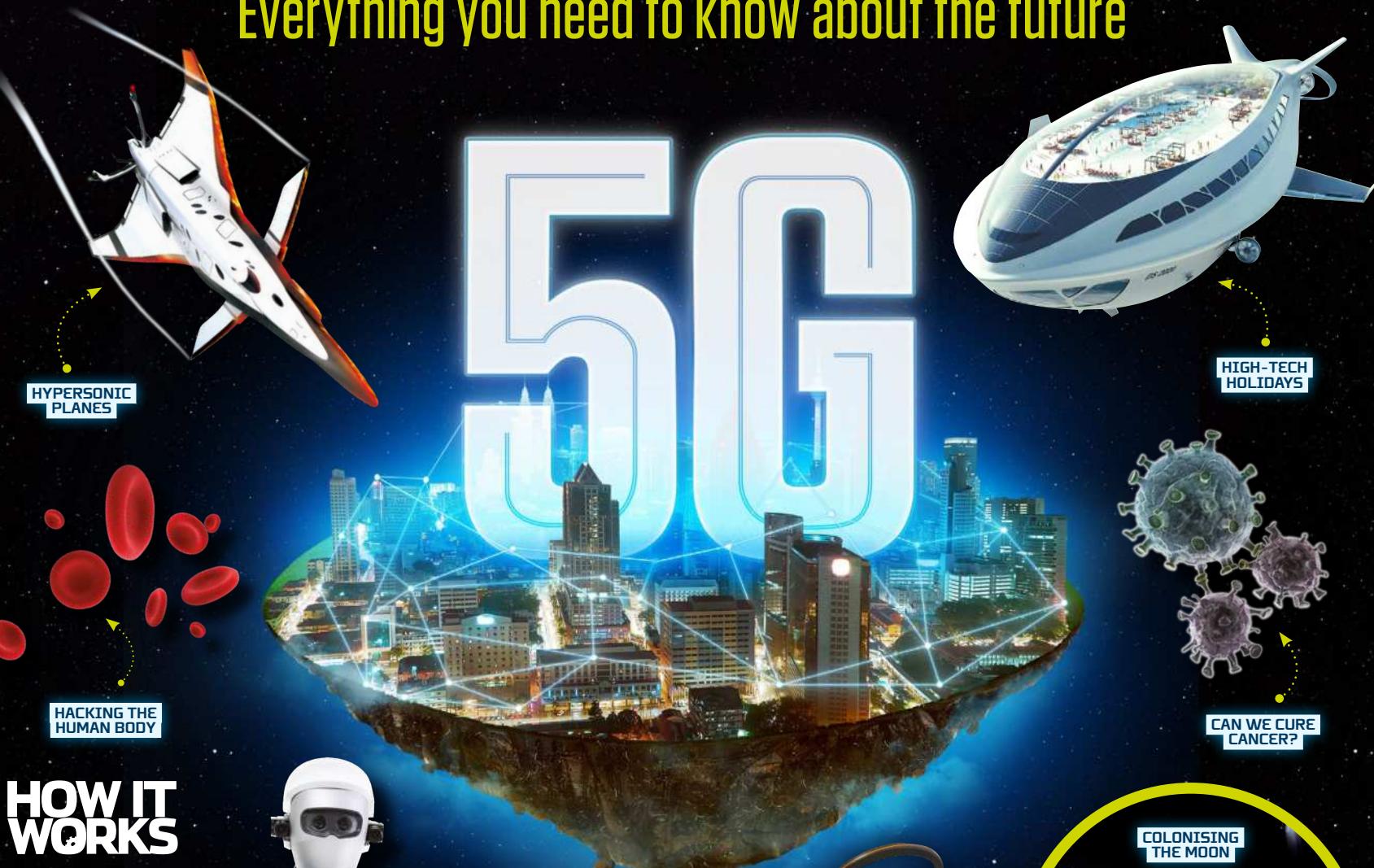


NEW

WORLD OF TOMORROW

Everything you need to know about the future

5G



HOW IT WORKS

Digital Edition

FUTURE

FIFTH EDITION

NEXT-GEN TRANSPORT • NANOTECH • SPACE TRAVEL

WELCOME TO

**HOW IT
WORKS**

**WORLD OF
TOMORROW**

Do you ever wish you had a crystal ball so you could take a peek at what is to come in the distant future? Well, now you can, with this new edition of How It Works World of Tomorrow! While it's no magical artefact, it does offer a glimpse of future developments in transport, medicine, entertainment and space travel based on the innovations taking place in the present day, and speculations made by scientists and engineers. Learn more about how humans will live, interact and better the planet we live on (as well as other planets) in the future. You can expect flying cars, moon colonies and bionic limbs, but you'll also discover whether you will be able to 3D print a customisable pizza, how technology will change our shopping experiences in the next 50 years and how we might cure big killers like cancer... Whether you want to know if we'll leave our roads and pavements behind, or whether we'll ever be able to take holidays to other planets, you will find the answer in this book. No crystal ball required.



J L
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WORLD OF TOMORROW

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Part of the

HOW IT WORKS

bookazine series

CONTENTS



WORLD OF TOMORROW

08 Inside the world of tomorrow



028
Flying vehicles

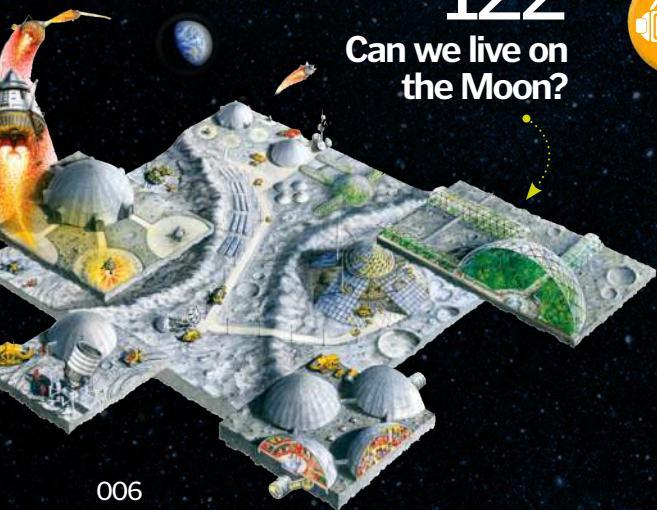


020
Hypersonic planes



TRANSPORT

- 20** Hypersonic flight
- 28** Fly to the future
- 36** On board the Dream Chaser
- 37** The rise of smart motorcycles
- 38** Next-gen emergency vehicles



122
Can we live on the Moon?



LIFESTYLE & ENTERTAINMENT

- 46** Future of food
- 52** 5G will change your life
- 60** How will we shop?
- 64** Travel 2050
- 70** Future of teaching
- 74** The Martin Jetpack
- 75** Your new smartphone is flexible



060
How will we shop?



070

Teaching the
next generation



116

Telerobotics



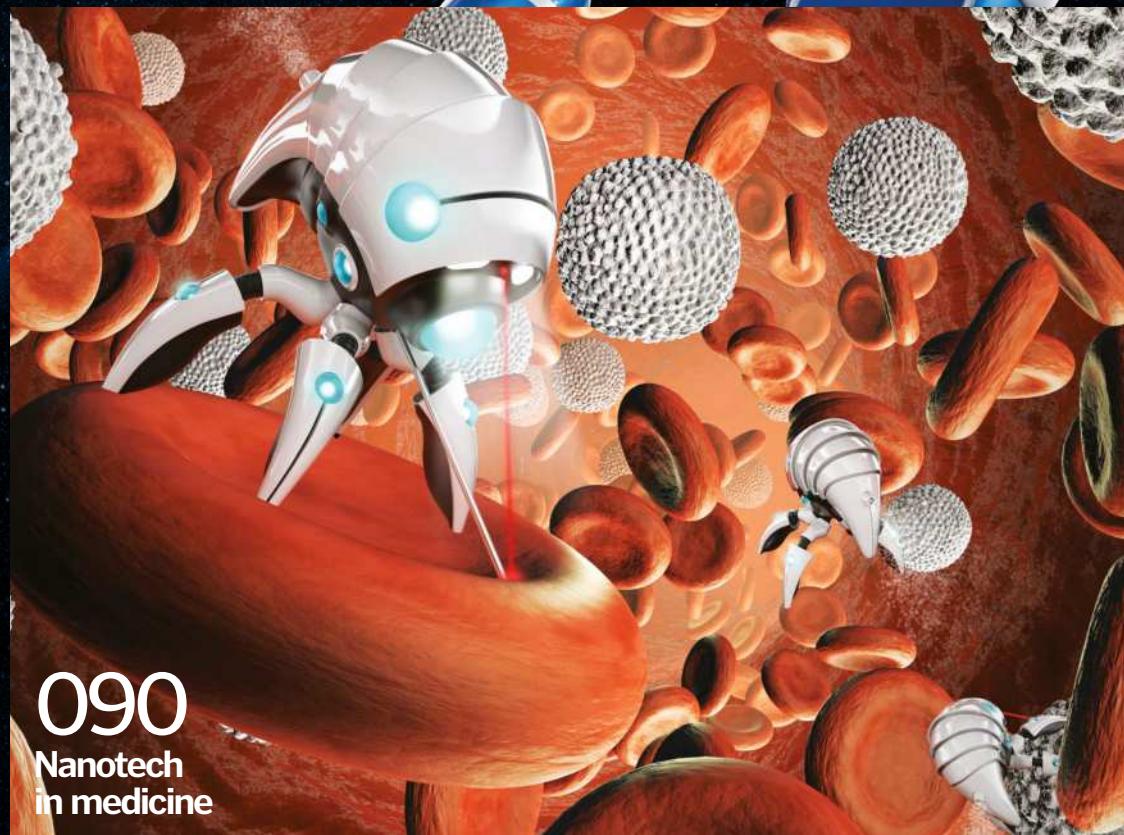
MEDICINE

- 78 Hacking the human body
- 84 The future of medicine
- 90 Saving lives with nanotech
- 98 The antibiotic apocalypse
- 100 How we'll cure cancer



SPACE

- 112 Osiris Rex
- 114 Inside Spaceport America
- 116 Remote-controlled explorers
- 120 Farming on alien planets
- 121 Rockets of past, present and future
- 122 Living on the Moon





INSIDE THE WORLD OF TOMORROW





Experience the lean, green cities we'll soon be living in

Major cities are often viewed as grey, energy-guzzling monoliths, but the cities of the future could change everything. As the planet's store of fossil fuels dries up, we are looking for new ways to power our cities in sustainable but spectacular-looking ways.

Skyscrapers will become towering greenhouses as vertical farming takes hold. Crops would be grown between storeys, taking advantage of the Sun's energy while using minimal ground space. These ecological super-buildings would have photovoltaic solar-cell facades and be topped by wind turbines, making these homes the ultimate self-sustaining structures.

Tomorrow's city centres could look very different as groups gather below solar powered trees. These so-called eTrees offer more than just shade, as the energy produced from the solar panels transforms them into mobile phone charging stations, free Wi-Fi and night lighting. The solar energy also activates an LCD screen that displays information such as the weather and educational content.

Building upward would allow plenty of room on the ground for urban social areas as well as luminous plants. These are implanted with light-giving compounds known as luciferins, which will make the greenery glow at night as a cost-effective and eco-friendly method of illuminating tomorrow's cities.

Far from being a scary, soulless world as shown in movies like *Judge Dredd* and *Blade Runner*, the future cities promise to be bright, spacious and green, making the most of the amazing natural resources we have at our disposal already.





TOMORROW'S TRANSPORT

Why getting from A to B will soon become a breeze

When you hear the term 'transport of the future' your mind will generally turn to flying cars. Excitingly, they're already on their way. AeroMobil has unveiled the third version of its flying vehicle. Capable of switching in seconds between car and plane, you could wing your way to your destination, free from traffic jams and roadworks. On the ground, the AeroMobil uses regular petrol and fits into any standard parking space, but can reach 200 kilometres (124 miles) per hour in the air thanks to its Rotax

912 engine. This would reduce the traffic in future cities, making the streets safer for people on the ground.

Also, companies such as Amazon and DHL are trialling drones that can deliver parcels under 2.3 kilograms (five pounds), which Amazon says makes up 86 per cent of their deliveries. The use of drones will clear the streets and air as they will be battery or solar powered.

If you still felt like you wanted to stay on the ground, however, driverless taxis could ferry



you around. The Google driverless car has already completed over 1,125,000 kilometres (700,000 miles) of accident-free driving using GPS satellites to map routes and on-board cameras to search for hazards.

These cars could be used as taxis – which would be summoned by a smartphone app – and would drive closer to each other and more efficiently than human drivers, meaning that no one need ever own a car. Unless it's an amazing flying car, that is.

Flying car

The plane-car hybrid that will change our travelling forever

Length

The 6m (19.7ft)-long body makes it 38 per cent longer than the 2014 Ford Focus, so bay parking might be tricky.

Fuel range

You can travel 875km (540mi) on the road and 700km (435mi) in the air, so you could travel the length of England.

Composition

The AeroMobil has a steel framework covered by a carbon coating, giving it strength and lightness.

Safety

In the event of an aerial problem, the AeroMobil has a parachute-deployment system.

Engine

The petrol-powered Rotax 912 engine throws out 100hp (74.6kW), making the aerial top speed 200km/h (124mph) and 160km/h (100mph) on the road.

Wings

The wings span 8.2m (27ft) and are fully collapsible, enabling the AeroMobil to act as a normal car.

Seating

There is only room for two people, so it's probably not ideal for families!



DID YOU KNOW? Even though it's a flying car, the AeroMobil uses regular gasoline



Delivery drones

At the moment delivery companies spend huge sums of money and use enormous amounts of fuel on delivering parcels, but in the city of the future drones could take on the task. Amazon and DHL are testing out drones that could deliver the majority of their products. These autonomous flying vehicles are lightweight and can be pre-programmed to reach their destination, guided by satellites.

They could deliver to hard-to-reach areas such as islands and take a huge number of vehicles off the roads. As they are powered either by batteries or solar power, they wouldn't be a drain on resources like delivery trucks either.

At the moment it is still illegal in the US for Amazon to use their drones for commercial reasons, although the company is in talks with the FAA to work around this. As the technology is already there it is looking increasingly likely that these devices could be in our skies within the next few years.



Driverless taxis

There is a very good chance that in the future, no one need ever own a car. Just like London and New York's bike-rental scheme, driverless cars could be summoned to your house and drive you to work. As they will drive themselves with much quicker reactions than humans and can't be distracted, they will be able to run at a steady speed, closer together and with fewer accidents, removing the main causes of traffic jams.

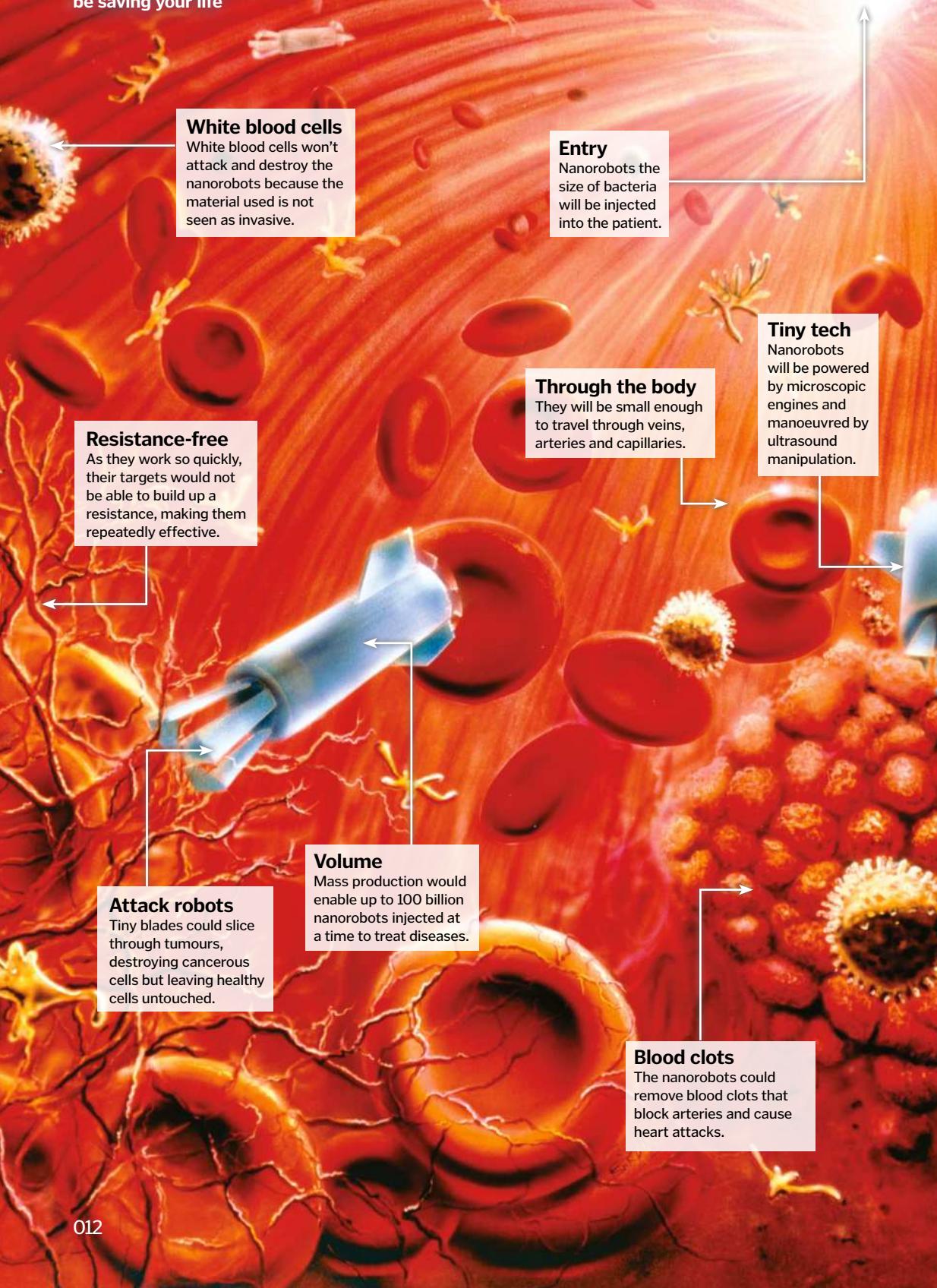
Rooftop cameras will use lasers to scan the road ahead at a range beyond that of human vision. A second camera will look to the sides for hazards like pedestrians or animals. The guidance system will use GPS, altimeters and gyroscopes to keep track of where it is and where it is going. As 90 per cent of a car's life is spent parked, autonomous hire cars could become the most efficient way to get around.



TOMORROW'S MEDICINE

Nanorobotics

The microsurgeons that will be saving your life



The microscopic tech that saves your life from within

The area of nanomedicine is one that is advancing so rapidly that doctors could soon be piloting miniature robots through your body to diagnose and even battle illness. It is expected that within 20 years, molecular manufacturing will have reduced the size of robots to roughly the size of bacteria, meaning they can enter the body to spot and even cure disease.

The minuscule robots could be programmed to behave like a white blood cell, seeking out illness-causing bacteria or germs, latching onto them and slicing them up into molecules too small to do any further damage. Doctors could then remove the robots by using an ultrasound signal to direct the robots toward the kidneys where they would get washed out in urine.

Another potential use for nanorobots in medicine is actual surgery. A set of chromosomes would be manufactured outside the body and attached to a nanorobot. This would head straight toward a diseased cell, remove the damaged chromosomes and replace them with the healthy ones.

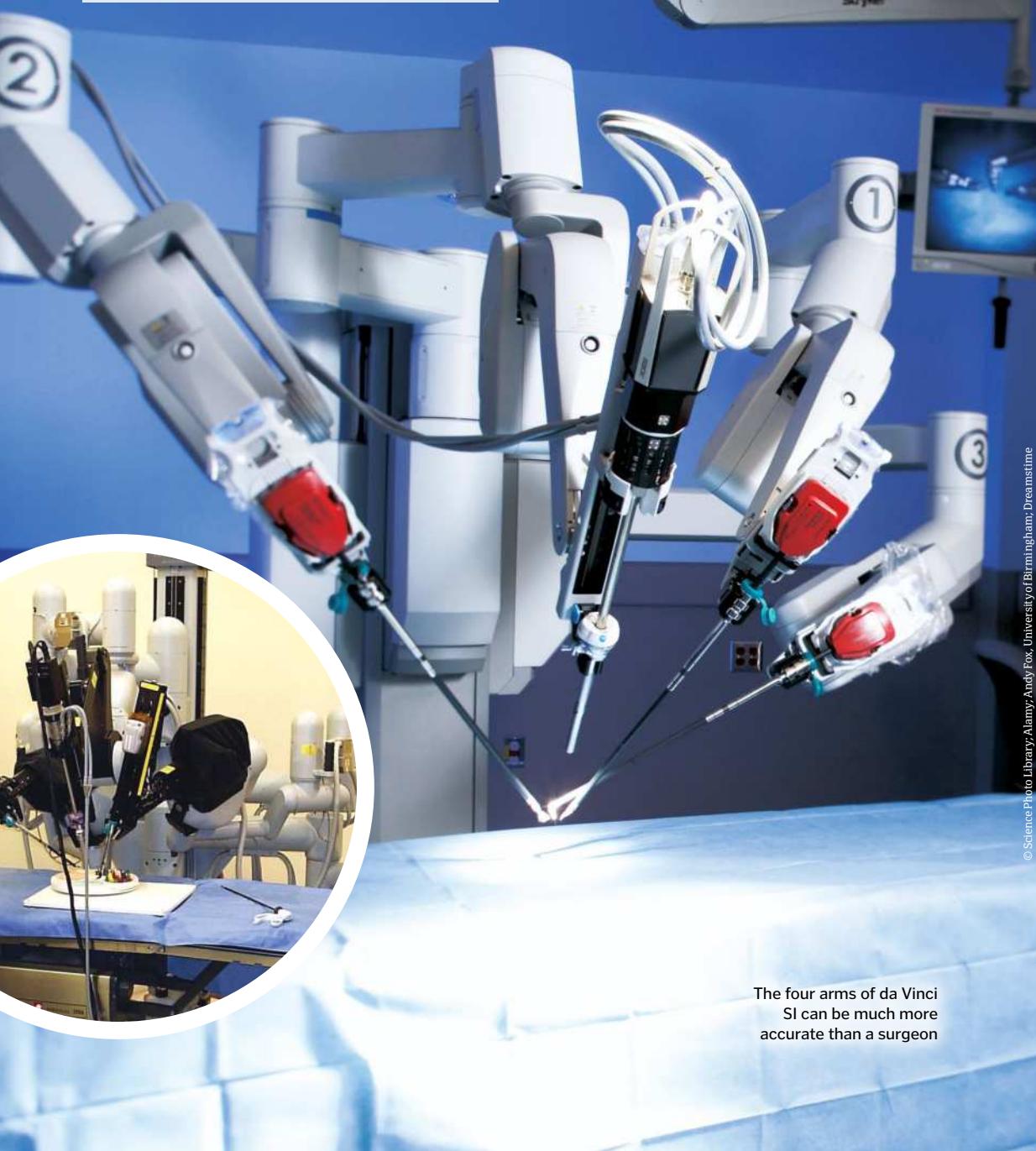
Another fascinating area of study is anti-ageing. Researchers have managed to restore the health of cells in a two-year-old mouse making it as fit as a six-month-old mouse. By injecting nicotinamide adenine dinucleotide (NAD) into the mice, scientists increased the level of communication between cells. This is very important, as a lack of communication between cells is heavily linked to diabetes, dementia and cancer. It's hoped that this scientific breakthrough will ultimately be proven successful in humans.

TOMORROW'S ROBOTS

The tech that will keep us happy, healthy and up-to-date

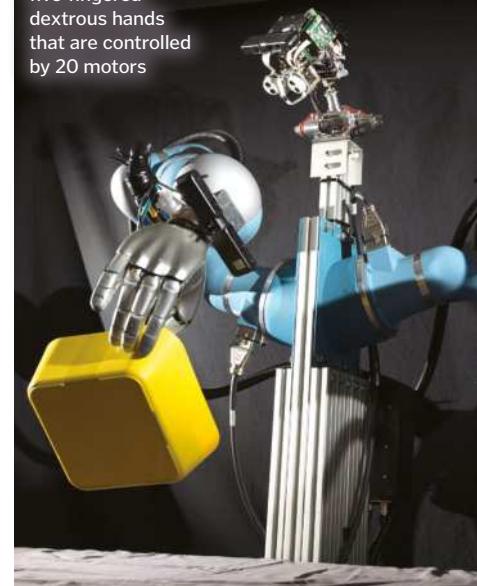
Medical

The da Vinci SI surgical robot is the world's most advanced robotic surgeon. It is operated via a master control unit that moves the four arms of the machine while the surgeon looks through an HD camera. This allows greater precision during surgery, greatly improving patient comfort and recovery.



The four arms of da Vinci SI can be much more accurate than a surgeon

Boris 2 has five-fingered dexterous hands that are controlled by 20 motors



Domestic

A robot called Boris 2 is one of the first in the world to intelligently grip unfamiliar objects. Developed by scientists at the University of Birmingham, the autonomous robot was designed with loading the dishwasher in mind – a chore that encompasses a range of general manipulation tasks.



Recreation

Pepper is a humanoid robot designed to live with us. Sensors are used to gauge your facial expressions, listen to you, learn your body language and react accordingly. It's a social robot that will try to cheer you up when you're sad by playing your favourite song, for example.



Could smart lenses replace your smartphone?



Smart lenses are contact lenses that display information such as routes, weather and your Facebook news feed into your peripheral vision. At the moment, the most likely team to crack this is Innovega with its iOptik contact lens, but this system still uses a pair of glasses that project semi-transparent screens onto the lens. The lens contains optical micro-components that change the angle of the light, focusing it into the pupil. This helps the wearer to focus on the near-eye object they otherwise wouldn't have been able to.

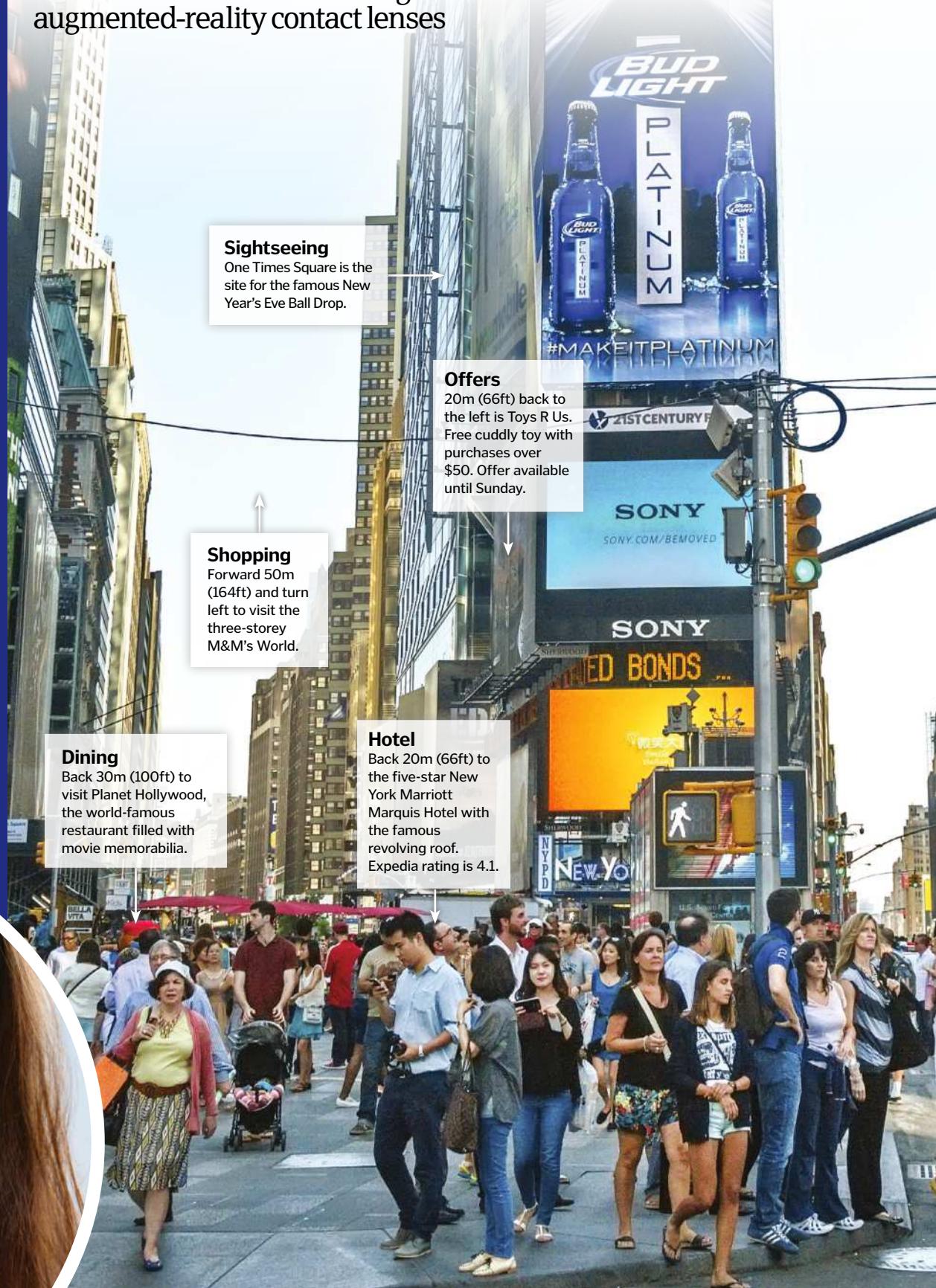
It is hoped that within three years a working prototype will be available that does away with the glasses entirely, using a microcamera embedded into the lens itself.

It is already possible for technology to be implanted into a contact lens. A team from South Korea has mounted an LED onto a normal contact lens, which shows the potential of adding technology to these optical aids.



AUGMENTED WORLD

Discover what we'll see through the augmented-reality contact lenses





Calorie counter
So far today you have walked 8.2km in two hours. This has burned 495 calories.

Weather
The current temperature is 18°C (64°F) and sunny. There is a ten per cent chance of rain.

Entertainment
Turn to your right to buy tickets for a range of Broadway shows including *Book Of Mormon* and *Matilda*.

Location
There are three of your Facebook friends within 1km (0.62mi). Connect with them?

TOMORROW'S ENERGY

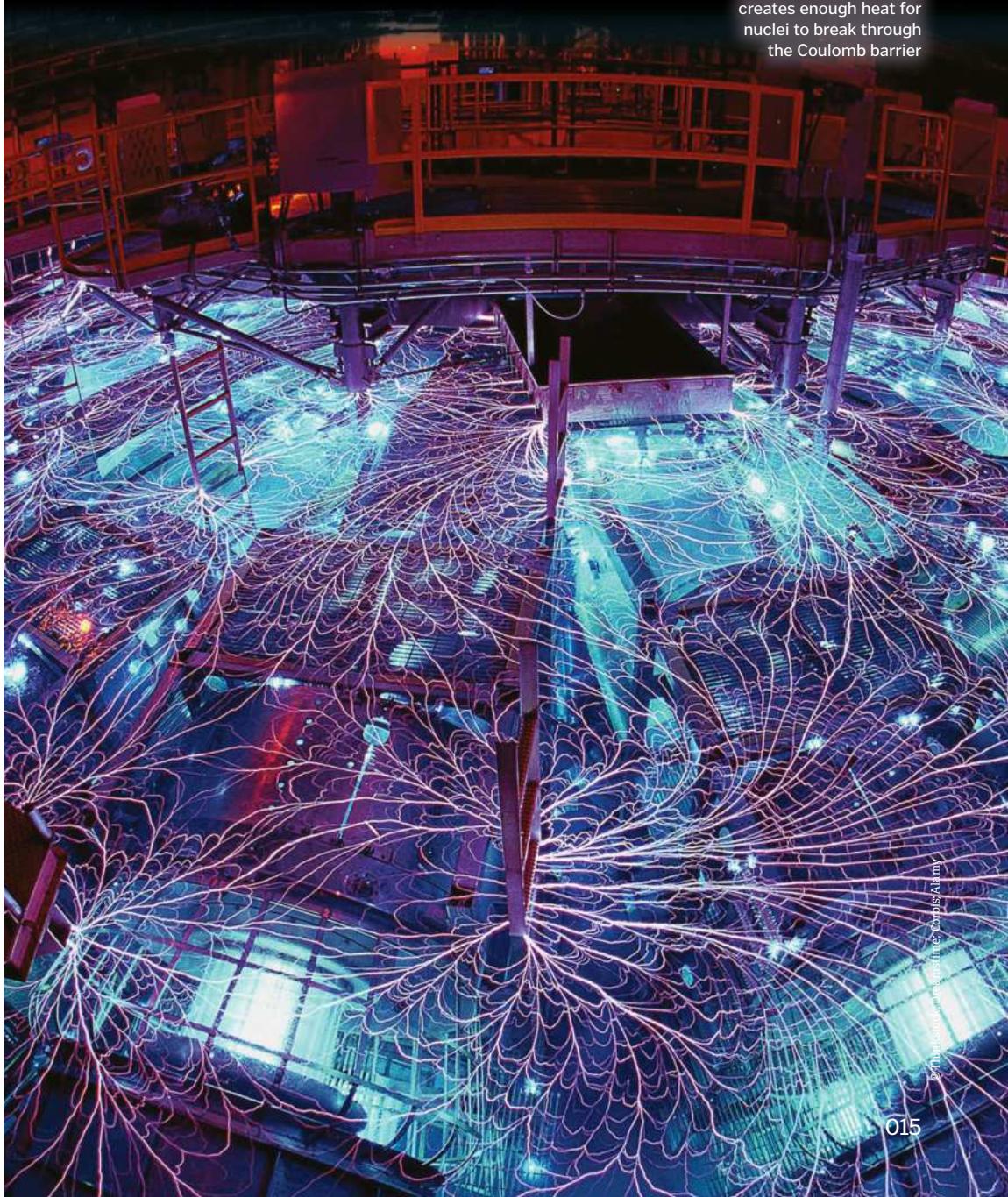
Fusion power: clean energy for tomorrow's power stations

Nuclear fusion is an incredibly exciting new direction that could provide Earth with huge amounts of clean energy. In nuclear fusion, helium nuclei are forced together to create a new atomic nucleus. The atomic mass of the two nuclei is greater than the mass of the resulting nucleus, so the extra mass is given off as energy. This can be harvested for practical uses.

The main barrier to nuclear fusion is temperature. Nucleons are held together by strong forces, while an electromagnetic force tries to pry

them apart. When protons come into close contact, the electromagnetic force pushes them apart in what is called the Coulomb barrier. 40 million degrees Celsius (72 million degrees Fahrenheit) of heat is needed to break through the Coulomb barrier and allow the nuclei to fuse. This extreme heat could be provided by the Z Machine produced by Sandia National Laboratories, USA. This machine uses electricity to create radiation that heats the walls of the facility to nearly 2 billion degrees Celsius (3.6 billion degrees Fahrenheit).

The amazing Z Machine creates enough heat for nuclei to break through the Coulomb barrier





COLONISING MARS

The tech that will help us go where no man has gone before

Ever since Neil Armstrong set foot on the Moon, there have been dreams to colonise other bodies in the Solar System, something that is becoming increasingly viable thanks to advancements in space travel and space suits.

Voyager 1 has travelled just short of 20 billion kilometres (12.4 billion miles) from planet Earth, but so far, humans have only reached the Moon, which is 384,400 kilometres (239,000 miles) away. The main reasons behind the difficulty of sending humans further distances are fuel storage, costs and the comfort of the astronauts. At least one of these conditions has to be compromised for a long-distance journey into space and that has held us back.

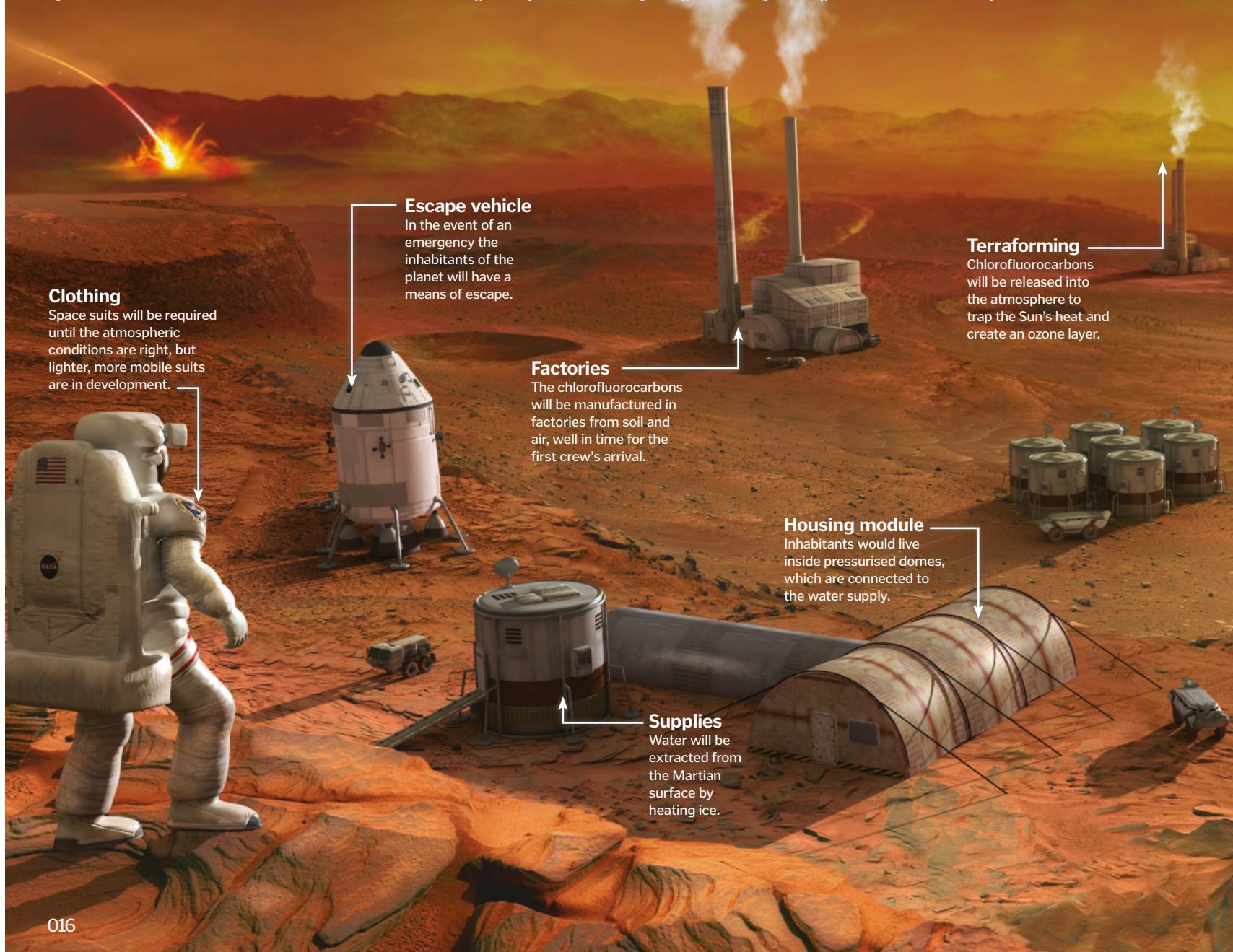
The reaction between nano-aluminium powder and water creates a powerful blast of hydrogen gas and aluminium oxide. This provides the thrust for a rocket to launch without weighing too much. Solar technology, will also reduce the reliance on fuel, lightening the load.

MIT has developed a skintight space suit that essentially shrink-wraps the astronaut, providing counter-pressure to the atmosphere. This will be much lighter and more flexible than current space suits, making extended periods of wear much more bearable.

3D printing has paved the way for missions in space to be much more streamlined. The ability to design and print almost anything from a tiny

bolt to a huge satellite dish means that missions can leave without bulky payloads on board.

All these advances in technology have pushed forward the possibility of inhabiting another planet. Mars One is a now-defunct project that optimistically aimed to have humans living on Mars by 2025. They hoped to achieve this by sending up rovers and life-support units, which would have sought out a location close enough to the poles for water, the equator for solar power and flat enough to build on. The life-support units would have leeched water from the soil by heating subsurface ice. Some would've been stored and some used for oxygen, nitrogen and argon, to make the atmosphere breathable.



Reaching Mars

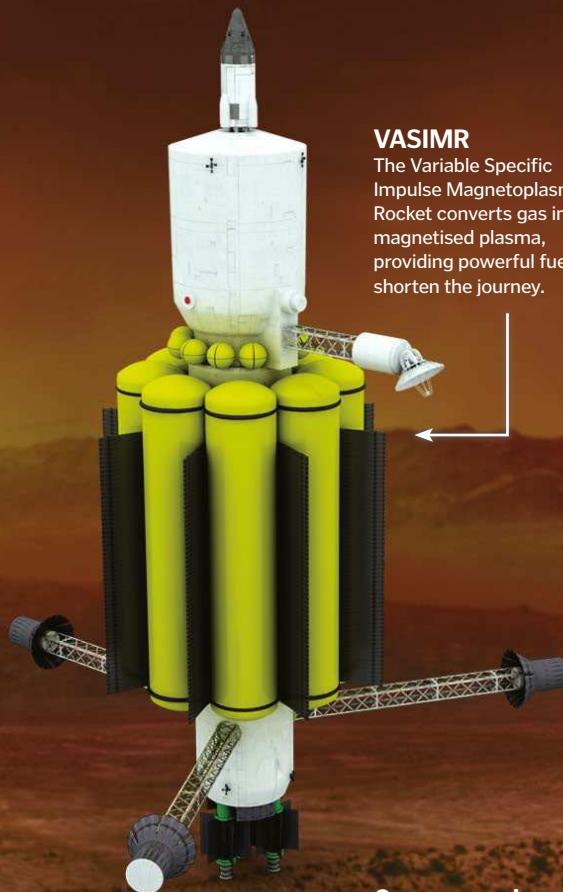
To make it to the Red Planet, new spaceships are needed
- these are the best ones currently in development



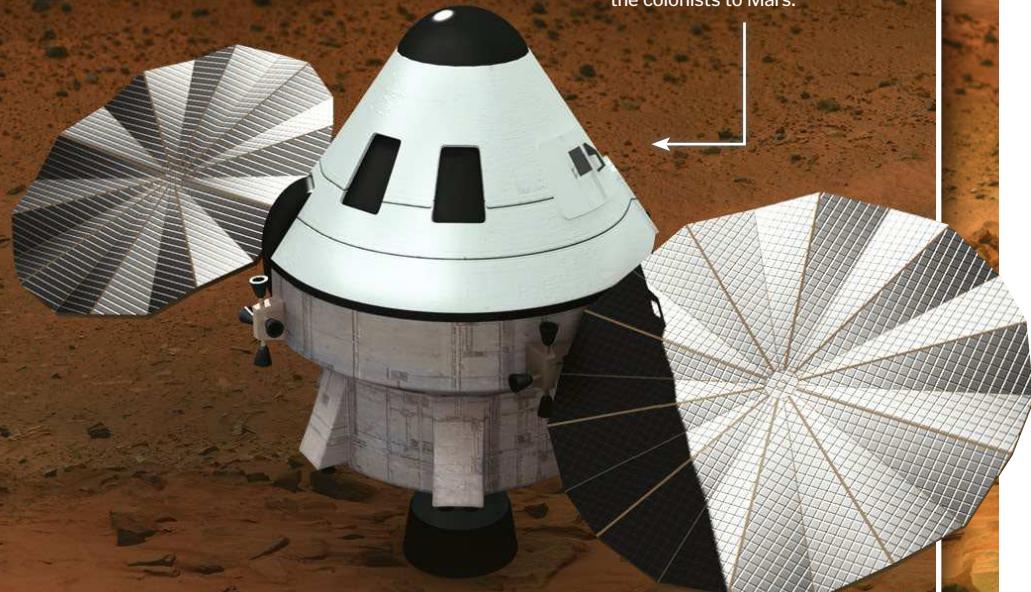
Falcon 9
A two-stage reusable rocket that will take the spaceship to Mars. It is designed by private space company SpaceX.



Saturn V
King of the Apollo era, NASA's three-stage rocket successfully launched 13 times. A similar design, such as NASA's Space Launch System (SLS), could also take astronauts to Mars.



VASIMR
The Variable Specific Impulse Magnetoplasma Rocket converts gas into magnetised plasma, providing powerful fuel to shorten the journey.



Crew capsules
NASA's Orion Multipurpose Crew Vehicle or SpaceX's Dragon capsule could carry the colonists to Mars.



TRANSPORT

020

Hypersonic flight



036

On board the
Dream Chaser

028

The future
of driving



20 Hypersonic flight

Soon enough, transatlantic flights will last a few hours

28 Fly to the future

Will we leave our roads behind in favour of the skies?

36 On board the Dream Chaser

This autonomous space plane has a great journey ahead of it

37 Smart motorcycles

BMW is looking to create the new motorcycle standard

38 Next-gen emergency vehicles

Ambulances and police cars will be bigger, faster, and safer



037
Biker
glory

5 TIMES THE SPEED OF SOUND

HYPersonic FLIGHT

Inside the planes
that will smash
supersonic
records



Blink and you'll miss them, but you'll definitely hear them. Hypersonic aircraft may look similar to the jet planes we're familiar with, but these engineering marvels are completely different beasts. Able to attain speeds that would literally tear a conventional passenger jet apart, hypersonic aircraft possess unique engines, are built from advanced materials and are packed full of intelligent tech.

So just how fast are they? By definition, a supersonic vehicle can move faster than the speed of sound – or Mach 1 – which is 1,235 kilometres per hour, or 343 metres per second. But to be classed as hypersonic, planes must fly at least five times this speed – 6,175 kilometres per hour, or 1,715 metres per second. And their speed isn't limited to Mach 5; that's just the

beginning. We've already created aircraft that can reach Mach 20 – that's nearly seven kilometres per second! As long as these vehicles can withstand the pressure in the atmosphere, they can keep moving faster and faster.

For over 30 years we were able to use Concorde to fly at supersonic speeds. It broke through the sound barrier and revolutionised air travel. But now the aim is to go faster than ever, with jets and commercial airliners capable of reaching even greater speeds. This is, of course, no simple task, but little over a century after the Wright brothers first took to the skies, we're still

building new and innovative aircraft. This technology reveals new realms of possibility that would make air travel more efficient and convenient than ever before. Imagine travelling halfway around the world in just a few hours, or seeing a spacecraft climb into the upper atmosphere without a gigantic rocket.

The most exciting part is that this isn't the stuff of science fiction – we've already flown vehicles at hypersonic speeds, and researchers are now developing hypersonic planes suitable for public use. Read on for more of these incredible feats of engineering and the faster world that awaits us.

"Hypersonic aircraft attain speeds that would tear a conventional passenger jet apart"

Hypersonic vs supersonic

For many years experts believed it was simply impossible to fly faster than the speed of sound. But that all changed in the 1940s, when US test pilot Chuck Yeager flew faster than Mach 1 – the speed of sound – for the first time in human history.

Onlookers below heard the sonic boom as the pressurised air gave way to the Bell X-1 rocket plane, and they realised that supersonic aircraft were dealing with new extremes.

But although supersonic aircraft have to overcome many obstacles to break the sound barrier, these factors are compounded when moving at hypersonic speeds. At Mach 5 and above, the air does more than just form shock waves. At such high speeds, the air heats the surface of the aircraft to very high temperatures – enough to melt steel – and the engines have to cope with huge pressures.

What causes a sonic boom?

Why breaking through the sound barrier is such a noisy affair

Continuous boom

An aircraft travelling faster than Mach 1 is constantly producing shock waves, which merge to form a cone. In certain conditions, this is visible as a conical cloud of water vapour.

Around 75 passengers could be transported at Mach 10 inside the Skreemr

Below Mach 1

The aircraft compresses the air in front as it moves forward and emits noise from its engines, forming waves that move away at the speed of sound.

SUBSONIC SPEED

Wavefronts

MACH 1

At Mach 1
When the aircraft reaches the speed of sound, the air being compressed cannot move away fast enough, so the waves accumulate at the nose of the plane.

SUPersonic SPEED



Above Mach 1

As the plane exceeds the speed of sound, it overtakes the waves. This causes a change in air pressure, or a shock wave, which is heard as a sonic boom.

BUILDING A HYPERSONIC VEHICLE

The challenges and successes in the engineering community's quest for hypersonic flight

Supersonic aircraft such as Concorde differed greatly from their subsonic counterparts. They had adapted wing designs and advanced engines. These changes allowed Concorde to smash through the sound barrier, which is something subsonic commercial jets were simply unable to do.

The difference between a supersonic and a hypersonic aircraft is even more striking, because at hypersonic speeds the rules change completely. The previously benign air starts to become a serious problem, as aircraft moving at hypersonic speed generate huge amounts of friction. This results in temperatures hot enough to melt the frame of a standard jet, so hypersonic aircraft must be built from robust heat-resistant

materials such as ceramics. And they can't stop there, because even if they are able to withstand the heat, the pressure at low altitudes is simply too great to fly at hypersonic speeds. Hypersonic vehicles need to climb high up into the atmosphere, where the air is much thinner, in order to lessen the strain on the aircraft.

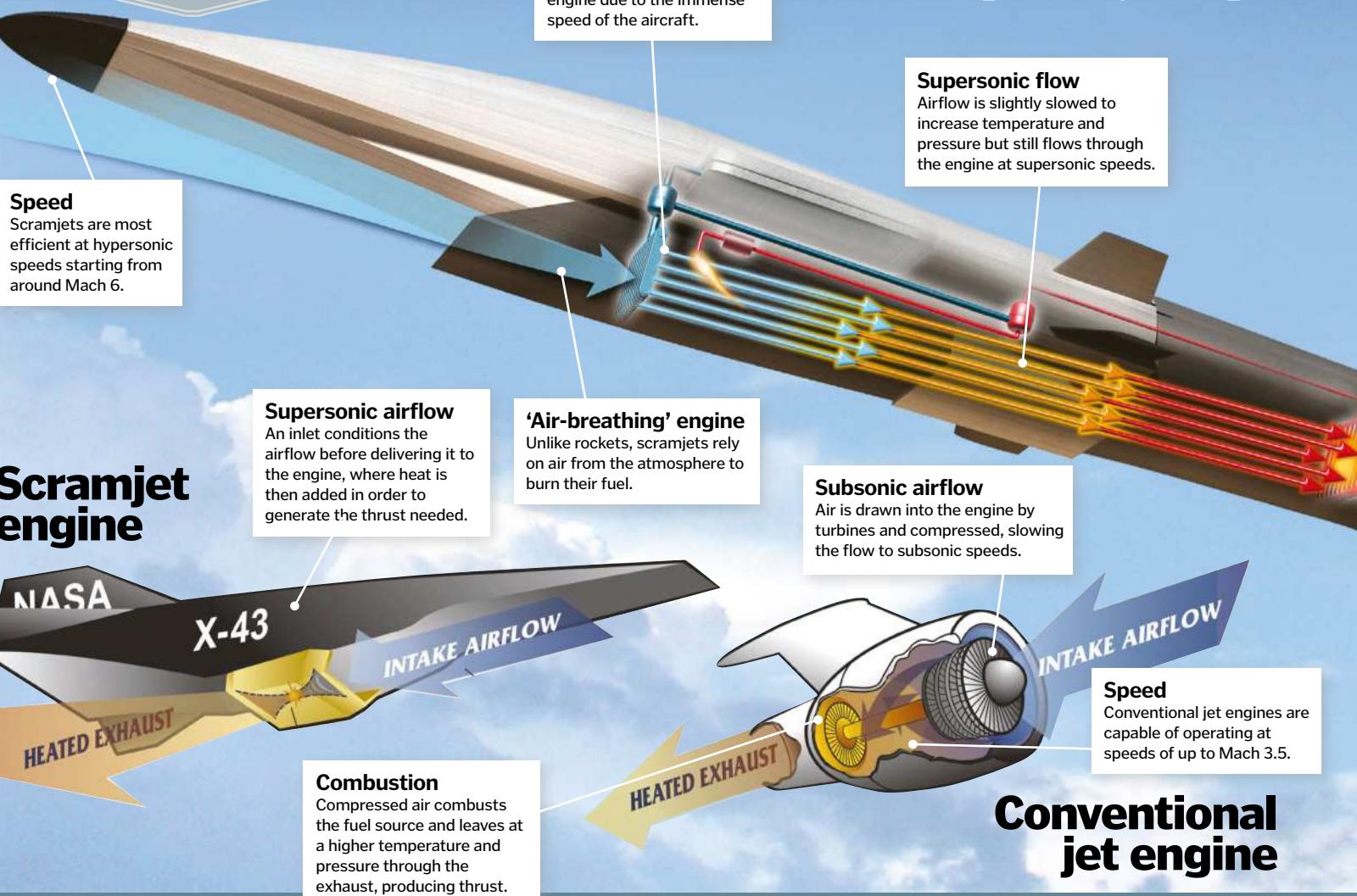
Perhaps the biggest consequence of the intense airflow is that hypersonic vehicles can't even use the same engines as subsonic aircraft. Air moving through supersonic plane engines does so at subsonic speeds (the supersonic airflow is slowed by an engine inlet), but if you tried using a similar setup when travelling at hypersonic speeds, it would melt or simply explode before your eyes. But rather than rely on

rocket engines – the only proven systems to power hypersonic vehicles – engineers asked themselves a more ambitious question: could we take what we've learned about the jet engine and design an equivalent that works at high supersonic, and even hypersonic, speeds?

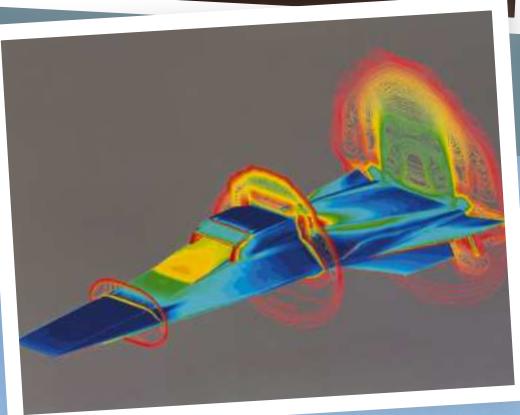
This led to the invention of the supersonic combustible ramjet, or scramjet. Taking the principles of a jet engine and stripping away all of the unnecessary components for hypersonic travel – such as a turbine and a compressor – allows air to move through much more quickly. With few moving parts, these simple-looking engines produce enough thrust for an aircraft to soar at incredible speeds; and in doing so, have started to bring the future of air travel to life.

The scramjet

Meet the supersonic combusting scramjet, an engine that thrives at hypersonic speeds



The Waverider's hypersonic design is partly incorporated into many of Boeing's hypersonic vehicles



The X-43 was the first aircraft to travel at Mach 7, enduring 1,650 degrees Celsius in the process

Thrust

Pressurised air combusts the fuel source and produces thrust as it exits the engine.



MAKING HYPERSONIC FLIGHT A REALITY

We spoke with Boeing's chief scientist of hypersonics, Dr Kevin Bowcutt, about the future of high-speed travel

Dr Kevin Bowcutt is the senior technical fellow and chief scientist of hypersonics at Boeing. He is an AIAA Fellow, a Fellow of the Royal Aeronautical Society, and also a member of the National Academy of Engineering. He holds BS, MS and PhD degrees in aerospace engineering from the University of Maryland, US.

Why is Boeing so interested in hypersonic technology?

Boeing is interested in hypersonic technology for several reasons, including application to missiles, aircraft, and space planes. Hypersonic airplanes may someday whisk passengers and cargo across oceans in an hour or two, enabling international day trips. Perhaps most exciting of all, reusable hypersonic space planes may make transportation to Earth's orbit more like flying in an airplane than a rocket, and therefore much more affordable – up to 100-times cheaper.

What hypersonic technologies are you currently developing?

Key enablers to make hypersonic flight a reality include lighter and more durable high-temperature materials, increased hypersonic engine efficiency, and advanced sensing and data analysis technologies. On the technology front we are developing advanced high-temperature ceramic matrix composite materials, structures, and thermal protection systems. We are also developing, and have applied, advanced hypersonic vehicle design methods based on multidisciplinary design analysis and optimisation (MDAO). We have designed, and continue to study, hypersonic vehicle concepts such as missiles, reconnaissance aircraft, passenger airplanes, and reusable launch vehicles (space planes). We have built and successfully flown two scramjet-powered experimental vehicles, the NASA X-43A and the USAF/DARPA X-51A.

What are the main challenges you currently face?

Finding materials that withstand very high

temperature, and that are lightweight and durable, remains a challenge, although good progress is being made in their development. Scaling up scramjets to larger sizes (beyond small jet engine size in terms of air flow rate) and speeds above Mach 7 is another difficulty due to ground testing limitations. Integrating low-speed and high-speed propulsion systems into combined cycle engines is another area for further development; combined cycle engines are required to accelerate from zero to hypersonic speed. Additional challenges include vehicle thermal management and thermo-structural health monitoring, as well as designing highly integrated systems such as hypersonic vehicles, driving the need for MDAO. On top of this, adequate funding is a perennial problem, although the situation is improving.

What is the overall goal of your project?

While Boeing is not developing a hypersonic airliner, and does not see a near-term demand for the product, we continue to research many advanced hypersonic concepts and technologies, so that we are prepared if the market develops for such vehicles. The potential for hypersonic aircraft in the future will require further advances in several areas of technology, as well as market demand. Ultimately, we want to help create the future of flight: ultra-rapid global transportation and routine and affordable space access.

How do you picture the future of hypersonic flight?

Although it's likely to be a few decades away, I envision a future where Mach 5 airplanes fly people between international cities in a couple of hours, and space planes routinely fly people to a hub in Earth's orbit for connecting flights to the Moon or Mars. Eventually, these vehicles will be powered by clean, high-density energy, probably some form of safe nuclear power.





THE FUTURE OF HYPERSONIC FLIGHT

Exploring the concepts that could one day replace the jet plane

If there's one lesson that we've learned about hypersonic flight so far, it's that heat, weight and power are all major obstacles. Too much weight, and you can't reach the desired speed. Too much heat, and your aircraft will melt mid-flight. And then there's the question of how we can power our machine to hypersonic speeds and keep it there. Fortunately, solutions for each of these critical problems have been suggested – and some seriously cool aircraft have been designed in the process.

Innovative engineers such as Charles Bombardier have been at the forefront of these endeavours. His envisioned aircraft, called Skreemr, would take to the skies with the help of an electrical launch system such as a railgun – so we could be bidding farewell to runways one day. A railgun is an electromagnetic strip that uses electricity to launch projectiles at incredible speeds, and could be used to fire the Skreemr into the air. This would eliminate the need for tons of extra rocket fuel for take-off, reducing the aircraft's weight considerably.

Another design by Bombardier, known as the Antipode, could tackle the heat problem as well as the menacing sonic boom. By using counter-flowing jets of air that move outwards in front of the aircraft, the temperature generated from aerodynamic friction and the sound produced by the sonic shock waves would be significantly reduced. And these features would help the Antipode fly up to Mach 24, equivalent to 29,500 kilometres per hour! These designs are still some time away from being realised, but Airbus and Reaction Engines have recently generated two concepts that could have us cruising at hypersonic speeds that much sooner.

Rising to new heights

Airbus' Ultra-Rapid Air Vehicle will cruise over twice as high as today's airliners

Take-off

Jet engines attached to the fuselage would be used for taxiing and take-off.

Climbing

Once the aircraft has reached the lower stratosphere, the rocket engine ignites.

Hypersonic hopefuls

Rival aerospace engineers are tackling the same mission in two very different ways

Passengers

Up to 300 passengers plus baggage can be transported, ensuring ticket prices remain competitive with those of subsonic airliners.

LAPCAT A2 REACTION ENGINES

ULTRA-RAPID AIR VEHICLE AIRBUS

Airframe

The shape of the aircraft allows the pilot to maintain control across the full Mach range.

Mounted ramjet engines

These engines generate thrust once the aircraft has reached a high altitude and is travelling at supersonic speeds.

Rotating fins

Fins at the rear of the plane can switch between horizontal and vertical orientations for increased stability and speed control.

Rocket booster

As the turbojet engines are retracted, a rocket engine pushes the plane beyond Mach 1.

Accelerating

The aircraft breaks through the sound barrier while travelling vertically, causing the sonic boom to travel horizontally instead of towards the ground.

Cruising

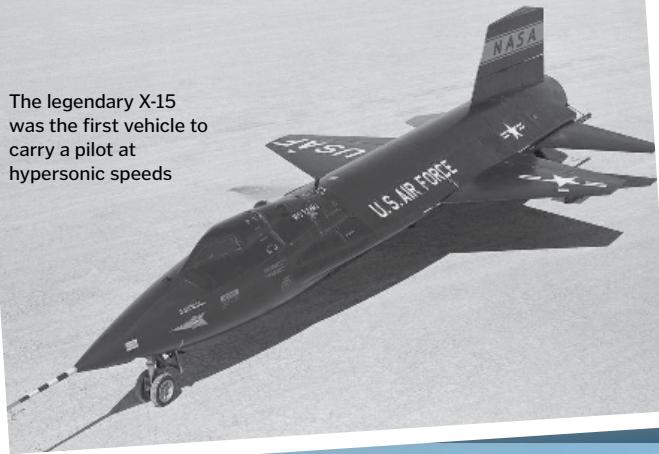
Advanced ramjet engines are ignited when the aircraft reaches an altitude of 35km.

The history of hypersonic travel

It's been 60 years since a piloted vehicle first travelled faster than Mach 5, breaking the hypersonic barrier in a defining moment that showed the true possibility of space travel. The X-15 aircraft not only showed us that we could be carried at hypersonic speed, but taught us about how best to design, control and safely land a vehicle capable of achieving such a feat. The aircraft itself was essentially a rocket/plane hybrid, built to endure temperatures up to 700 degrees Celsius and fly at an altitude of over 100 kilometres, while being blasted through the air by a rocket engine at the rear.

Its achievements filled its creators with confidence that they could soon launch a vehicle into space at high speeds and bring it back into the atmosphere safely. Essentially, the X-15 played a role in putting humans on the Moon.

The legendary X-15 was the first vehicle to carry a pilot at hypersonic speeds



Fuel
Almost half of the aircraft's weight – approximately 400 tons – is its fuel mass.

No view
Windows that can cope with the heat of hypersonic travel are expensive and heavy. Passengers may have internal screens linked to viewing cameras instead.

Fuel tank
Airbus' design would be fuelled by on-board liquid hydrogen and liquid oxygen, as well as ambient oxygen from the air.

Passengers
This concept can carry up to 20 passengers along with two pilots.

Turbo ramjets
A turbojet and a ramjet are combined into a single engine that is capable of take-off and landing, as well as cruising at hypersonic speeds.

Retractable turbojet engines
Conventional engines are used during take-off and are then withdrawn into the fuselage, making the vehicle more streamlined.

The Skreemr would make use of an electrical launch system to accelerate to high speeds

Two passengers would be able to reach the other side of the world in under an hour in the Antipode

© SPI Imaginative.org / Ray Mattison / Abhishek Roy; Illustration by Adrian Mann

"We could be bidding farewell to runways one day"

HIGH-SPEED HOLIDAYS

It may soon be possible to watch the Sun rise in Paris and set in Tokyo

Most of us see travelling to the other side of the globe as the trip of a lifetime. Aside from the expense, these journeys take a very long time indeed. When we have to watch hours upon hours of in-flight entertainment on long-haul flights, it feels like we're lumbering through the air.

Ever since the world lost Concorde in 2003 we've been content to fly within the sound barrier. But the answer to our travel woes could be to punch right through it and go faster than any passenger plane has before. By flying at the upper limits of supersonic speed and into the hypersonic region, we could dramatically reduce travel times and change the way we explore the world.

The unique design of the aircraft has become the main challenge for revolutionising air travel. Most passengers probably wouldn't be comfortable strapping into a rocket and blasting across the planet. Using a rocket for international travel would also be infeasibly expensive, complicated and bad for the environment. Ideally, the hypersonic passenger carrier of the future will operate much like today's subsonic airliners. Passengers would be able to take their seats in a pressurised cabin, and the vehicle would be able to take-off and land unaided on a conventional runway.

Engineers have decided that using multiple engine types is the way to get this technology off the ground. Typical jet engines could be used for take-off and landing; a rocket engine could then propel us to great heights and speeds; and then the supersonic or hypersonic engine could take over. This would nevertheless be something of a thrill ride, as some designers believe their aircraft would have to take off near vertically! Those of us with a nervous disposition to flying may find it best to stick to the relatively sluggish speeds of a jumbo jet. However, for those holidaymakers and businesspeople who want to maximise the time spent at their destinations, and are willing to brave a vertical ascent into the atmosphere, hypersonic journeys will be the way forward.

Rocket power
Rockets take over from the jet engines after take-off to increase the aircraft's speed to at least Mach 2.5.

Taking tourists to the upper stratosphere

Meet ZEHST, the Zero Emission High-Speed Transport of the future

Jet engines
Subsonic jet engines are required for take-off and a safe landing.

Oxygen tanks
Unlike the other 'air-breathing' engines, the rockets require a source of stored oxygen for fuel combustion.

Liquid hydrogen
Two tanks of hydrogen are used to fuel the rockets and ramjets.

Lightweight materials
To compensate for the weight of multiple engines, the frame must be lightweight yet strong enough to endure high levels of aerodynamic drag.

Ramjets
When the aircraft's speed reaches 3,100km/h, air can be 'rammed' through the ramjets fast enough for the engines to produce thrust.

A hypersonic vehicle could get you from London to Sydney in less than three hours



It would take a hypersonic vehicle only an hour and a half to travel from London to Cape Town



DID YOU KNOW? Travelling at Mach 5, you could circumnavigate the globe in less than seven hours

Suppressing the sonic boom

Whether you're going supersonic or hypersonic, breaking the sound barrier is loud. As a vehicle accelerates, the waves of air pressure being pushed along by the frame begin to merge into one single shock wave. This air can travel at the speed of sound but as a vehicle surpasses this speed, a drastic change in pressure results in a deafening clap – a sonic boom.

The sonic boom is one major hurdle for aviation companies to overcome if hypersonic flight is going to be made available commercially. Concorde – the first and only public transport to break the sound barrier – was criticised for its volume and was only permitted to break the sound barrier over the ocean.

Like many aerospace issues, it could be NASA that comes to the rescue once again. The space agency and its partners at Lockheed Martin are in the process of designing an aircraft with many lifting surfaces to stop the airwaves from combining. The result would be a series of small booms rather than one big one – lowering the sound output to that of a normal conversation.



NASA and Lockheed Martin's Quiet Supersonic Technology (QueSST) X-plane design will be a step towards 'low-boom' supersonic travel

Helium tanks

Helium is used to pressurise the propellant tanks, allowing liquid hydrogen to be combusted in the rocket engines.

Passenger cabin

Up to 100 passengers can be carried in the pressurised cabin.

"Hypersonic travel would change the way we explore the world"

High altitude

To minimise air resistance the ZEHST would climb 32km above sea level for its journey – three-times higher than a Boeing 747!

Streamlined design

The pointed nose and narrow wingspan, reminiscent of Concorde, maximise the aerodynamics of the vehicle.

Goodbye long-haul flights

Domestic hypersonic travel promises to make the world feel a whole lot smaller

NEW YORK

ZEHST

Boeing 787

Concorde

LONDON

London to New York flight times

1hr ZEHST
6,180km/h (Mach 5)

3.5hrs Concorde
2,180km/h (Mach 2)

8hrs Boeing 787
920km/h (Mach 0.85)



TRANSPORT

FLY TO THE FUTURE

Teased by science fiction for decades, flying cars may finally be getting off the ground



When *The Jetsons* debuted on television in 1962, astronaut John Glenn had just become the first American to orbit Earth. But during the optimism of the early space age, when rockets, satellites and nuclear power were on everyone's mind, it must have seemed like we would all be flying to work in a hover car like George Jetson within a few years. Yet despite ever more lifelike flying cars on screen — from Luke's landspeeder in *Star Wars* to those in the recent *Total Recall* remake — we're still waiting for them to make the leap from science fiction to science fact. However, that wait may soon be over.

Recent years have seen a flying car frenzy. At least two prototypes have been unveiled, with the Lilium Jet going on its maiden voyage in Munich and the Kitty Hawk Flyer publicly demonstrated in San Francisco Bay. Meanwhile, ride-hailing app Uber has announced plans to launch a network of airborne taxis in Dubai and Texas, and Slovakian company Aeromobil is now reserving its fleet of 500 flying super cars to buy.

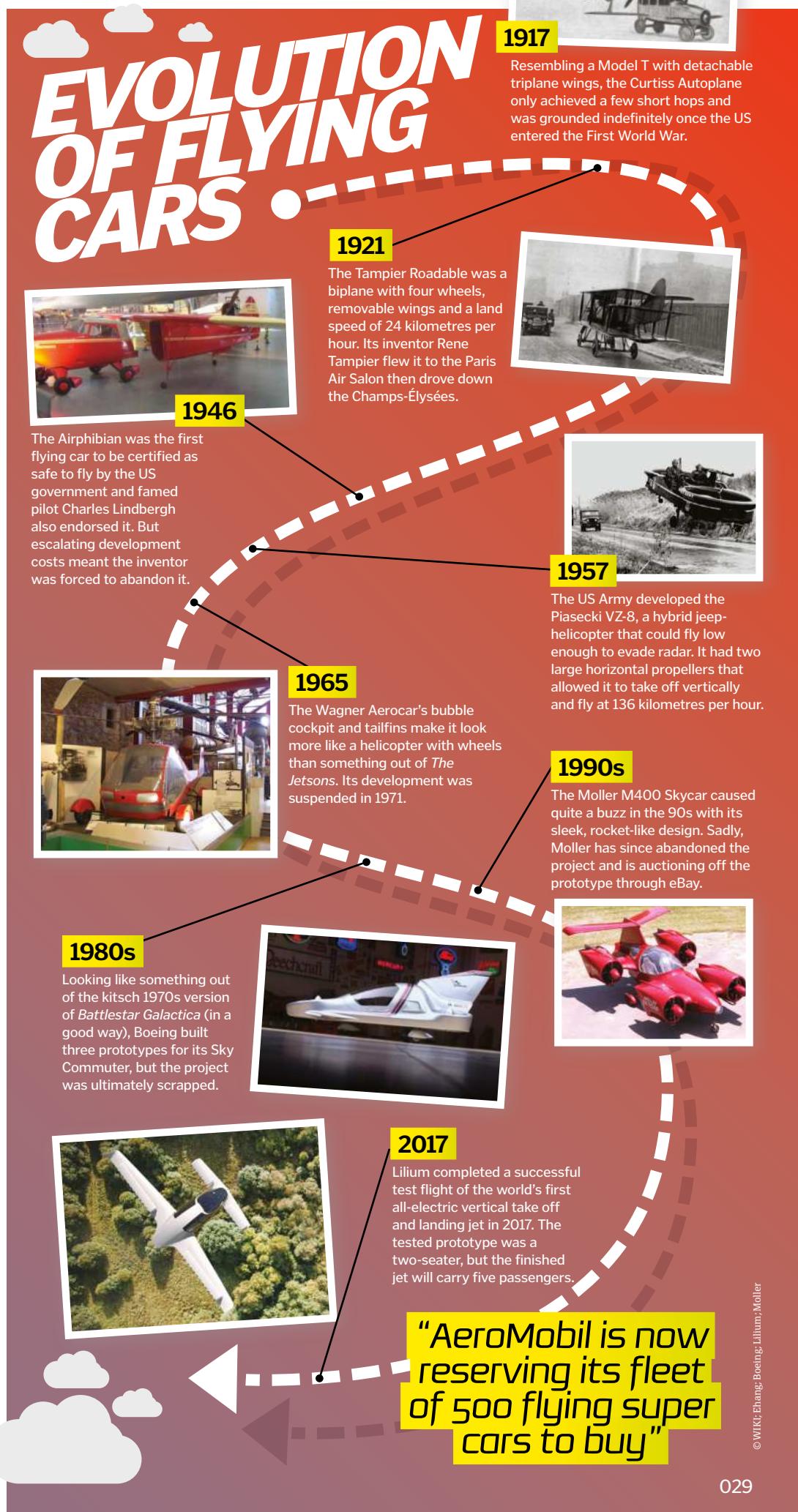
Google co-founder Larry Page has not only invested in Kitty Hawk recently but has also been funding another flying car company called Zee.Aero since 2010. Beyond the startup scene, both aerospace and auto industry giants, have also committed to developing honest-to-goodness flying cars.

So why now? The last few years have seen some major technological breakthroughs that could help flying cars finally lift off. Many of the designs we're seeing now use electric propulsion rather than jet fuel because battery technology has witnessed vast improvements driven by the demand for hybrid and electric cars.

While some concept vehicles still imagine humans in control behind the wheel, advances in so-called 'machine learning', which is essentially artificial intelligence, have led many companies to pursue self-driving flying cars. This means the user won't be required to own a pilot's licence, making flying cars more accessible for everyone.



For years little more than a fanciful sketch, flying cars are rapidly becoming a reality





The popularity of consumer drones, while much smaller and lighter, have also helped to drive down the cost of some components. In fact, the industries overlap; Chinese drone maker EHang are developing a self-flying taxi that looks like an oversized quadrocopter.

However, having been cruelly let down by pie in the sky fantasies about flying cars in the past, it's important that we stay grounded. Most of the manufacturers that have made announcements also say we won't actually be whizzing through the skies until around 2025. While the tech that underpins these vehicles is pretty much there, it will take years to fully develop them, carry out the necessary test flights and safety checks, as well as make the whole process simple enough that these flying cars could be affordably mass-produced.

Despite spurring on many of the innovations that make flying cars possible, Tesla CEO Elon Musk has reservations about flying cars. "Obviously, I like flying things," he told *Bloomberg*, referring to his other side line, private rocket company Space X. "But it's difficult to imagine the flying car becoming a scaleable solution." He also has concerns about mid-air fender benders. "If somebody doesn't maintain their flying car, it could drop a hubcap and guillotine you," Musk said. "Your anxiety level will not decrease as a result of things that weigh a lot buzzing around your head."

It's easy to dismiss Musk's skepticism due to the fact he is developing an entirely different form of transport that would see drivers travel in high-speed underground tunnels or 'hyperloops' rather than fly. However, many aerospace engineers and aviation experts have



FLIGHT OF FANCY? THE CHALLENGES FACING... FLYING CARS



expressed similar concerns about the danger of the sky filling up with commuter traffic as airports, urban helipads and air traffic control would come under unprecedented pressure.

As part of their plans to create a fleet of flying taxis, Uber have committed to building so-called 'vertiports'. On the one hand these are intended to ensure that landing pads are as accessible to users as their conventional, earthbound taxis. However, they'll also go a long way to easing demand on existing infrastructure.

Chinese firm EHang plan to build private air traffic control towers wherever their passenger drones operate. One of these 'command centres' is already up and running in Guangzhou, where EHang carry out their test flights. These centres will monitor the autonomous shuttles, receiving live feed readings, including speed, altitude, individual propeller power, and location. The staff will be able to view camera feeds from the drone and communicate with passengers inside.

These are only the first steps towards making our skies safe for airborne commuters; government agencies in every country will likely impose their own rules and restrictions. However, if rules for the sky can be established, flying cars have the power to transform not just the way we travel but how we live our lives.

Alternatively, if we all get used to living the high life, jetting from location to location, is there even any reason to return to street level?

Read on to discover how flying cars have evolved, the tech that makes them tick and what the future may look like when they finally fulfil our Jetson dreams.

Even if flying cars overcome all technical barriers, regulation — from safety standards to air traffic control — will be a major hurdle and likely take years for lawmakers to agree on. Self-flying cars will probably have to meet additional standards.

The Aeromobil's chassis is made almost entirely out of ultra lightweight carbon fibre

Simple storage

The TF-X's wings fold up so compactly the vehicle can be stored in a standard parking space or garage.

Cruising speed

The vehicle will reach 322kph and have a 805km flight range.

Rechargeable batteries

The vehicle's petrol engine can either recharge its electric motors or they can be plugged into an electric car charging station.

Fuel consumption

It takes a lot of power to defy gravity, which can be expensive and polluting. Advances in battery tech might offer an alternative, but jet fuel still packs more energy per kilogram, a key consideration in an industry where weight trumps just about everything.

Regulation



The flying car in disguise

The Aeromobil is a real-life Transformer. To see it in driving mode you could mistake the slick carbon fibre Aeromobil for some kind of experimental supercar. But in just three minutes this sporty two-seater can be ready for take off as wings unfurl from its roof and a rear propeller pops out at the back. Then all you need is an airfield or a long stretch of empty road and you're cruising at 10,000 feet. Unfortunately, the Aeromobil is also being sold like a supercar — only 500 are being made and each one will cost \$1.2 million (£908,400).

Hybrid power

In the air, the propeller is driven by a gas-guzzling, four-cylinder engine. On the ground, this acts as a generator, driving electric motors in the front wheels.

Ballistic parachute system

In case of an emergency, the Aeromobil deploys a whole-aircraft parachute to slow its descent.

Digital cockpit

The driving seat is surrounded with digital displays showing necessary information for both driving and flight modes.

Licence to thrill

While you need both a driving and pilot's licence to operate the Aeromobil, the aim is for future versions to be fully autonomous.

Flying high

Classed as an ultralight aircraft, it has a top air speed of 360kph and a range of 750km.



Vertical take off

The TF-X's propellers will shift from a vertical to a horizontal position and be powered by a 300-horsepower engine.

Easy rider

The vehicle will be certified as a Light Sport Aircraft in the US so that it can be flown with a pilot's licence that only requires 20 hours training.

The TF-X is (almost) ready for vertical take off

Terrafugia (Latin for 'escape the Earth') has been developing flying cars since 2006. Its most exciting concept, the TF-X, looks like a four-seater SUV with fold-up wings. But its most exciting feature is that its propellers can shift position so that the TF-X can vertically take off and land (VTOL) like a helicopter — meaning it doesn't require a long runway — before switching to conventional horizontal flight. Terrafugia has been teasing flying car tech for years now, but its recent purchase of Volvo's parent company Geely might get the TF-X off the ground.

Noise pollution

As anyone who has heard a helicopter land or flown a drone will know, VTOL vehicles, which generate a lot of downward force, make a lot of noise for people on the ground. This will not endear flying cars to the public.



Qualified pilots

Even if the controls can be simplified (perhaps with the aid of AI), flying a vehicle requires a different set of skills to driving. Alternatively, hiring a pilot to fly you can cost £500 (\$660) an hour.

H

"Many engineers have expressed concerns about the sky filling with traffic"

Infrastructure

Most major cities boast a few helipads, but these are not designed to handle heavy commuter traffic. Uber plans to build its own urban vertiports to ease the burden, but these will have to meet strict regulations and will possibly face opposition from local residents.



SKY RIDE

These airborne options plan to offer customers low-cost, short-distance rides

A realistic flying machine

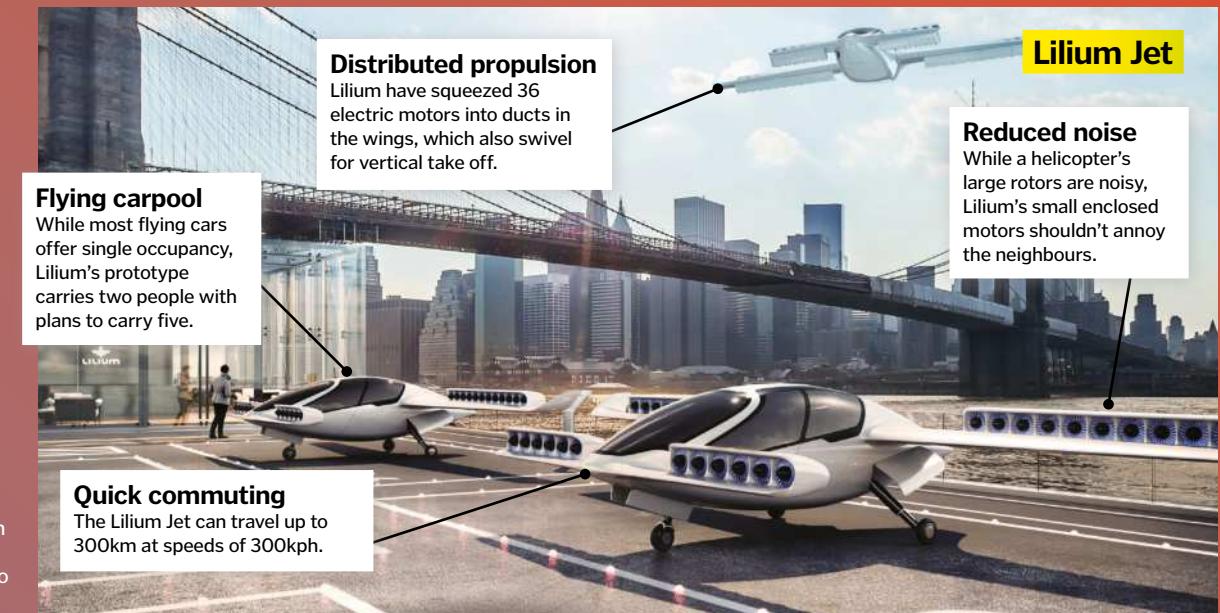
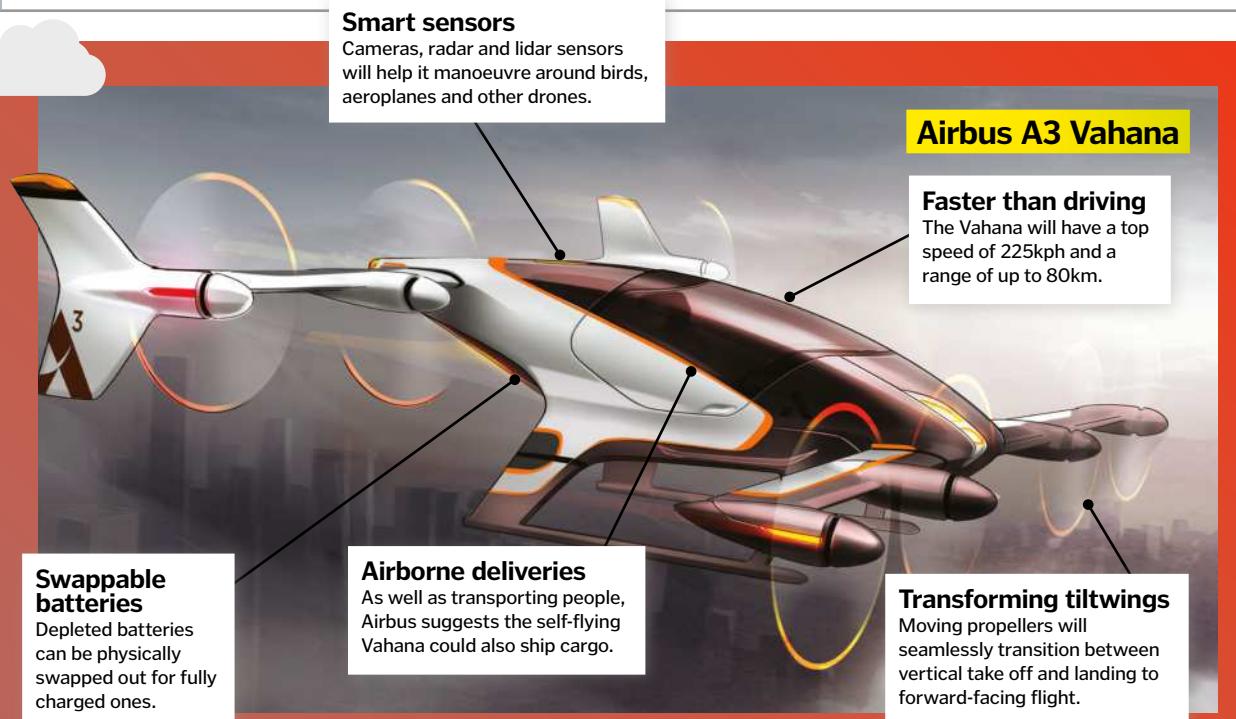
While there are lots of startups promising they will invent the flying car first, Airbus is approaching the challenge with nearly 50 years experience building real-life planes. While it looks like something out of science fiction, the Airbus A3 Vahana (pronounced 'A-cubed') is designed around existing wing and landing gear technology. A full-sized prototype is already in the works, with demonstrations promised before the end of 2017.

The Lilium Jet doesn't actually use jet fuel

In April, the Lilium Jet made its maiden voyage at a Munich airfield, proving that this all-electric aircraft can take to the sky. However, its flight only lasted a few minutes, with no one in either of its two seats and a pilot controlling it from the ground. Backed by the European Space Agency, Lilium is confident it can develop the battery power needed to offer an on-demand taxi service by 2025.

The self-piloting drone that you can ride inside

The 1.4-metre-high EHang 184 can fly passengers distances of up to 16 kilometres at around 100 kilometres per hour. The 184 flies itself, so all you have to do is punch your destination into a smartphone app that connects with the 184 via the vehicle's built-in Wi-Fi and off you go. Though a summer trial had to be rescheduled, EHang are expected to buzz passengers around Dubai soon.



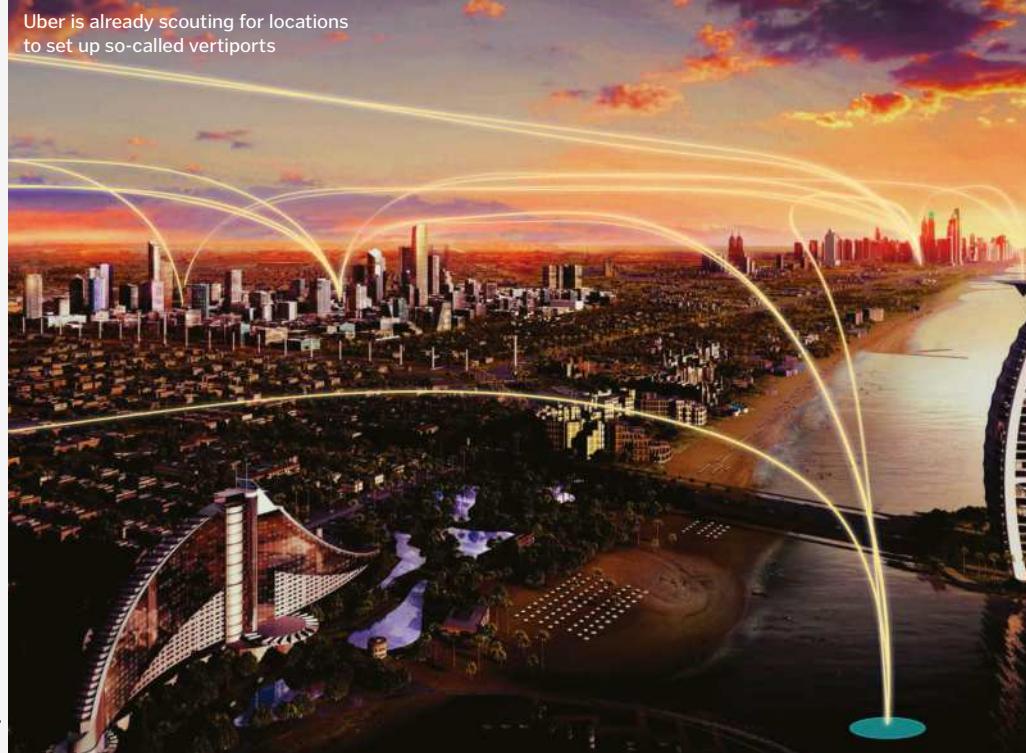
Up, up and Uber!

Ride-hailing service Uber has announced it is also taking to the skies. The company will trial UberAIR flying taxis in Dubai and Dallas, which passengers will be able to summon using its regular mobile app.

"Urban aviation is a natural next step for Uber in this pursuit, which is why we are working to make 'push a button, get a flight' a reality," said Uber's chief product officer Jeff Holden at a press event. Holden added that while these flights will initially involve manned aircraft, they will eventually be cheaper, faster and more environmentally friendly than conventional Uber rides as they will use autonomous electric aircraft.

Uber has hired Mark Moore, a NASA aircraft engineer renowned for his VTOL work, and partnered with several aeronautic manufacturers to develop these vehicles. Once operational, Uber also plans to build vertiports — landing pads with charging ports — in easily accessible urban areas.

Uber is already scouting for locations to set up so-called vertiports



UberAIR will operate a network of aircraft flying distances of up to 40 kilometres

TOP 5 FICTIONAL FLYING CARS



Chitty Chitty Bang Bang, *Chitty Chitty Bang Bang* (1968)

Created by eccentric inventor Caractacus Potts, the family-sized Chitty Chitty Bang Bang can fly the length of Europe and has a floatation device for evading pirates on water.



Scaramanga's AMC Matador, *The Man With The Golden Gun* (1974)

Bond villain Scaramanga used a Coupé that transformed into a plane for a daring kidnap. 007 mentions it flying "200 miles west of Bangkok".



Police Spinner, *Blade Runner* (1982)

Ideal for patrolling the skyscrapers that loom over futuristic LA, the police cars in Ridley Scott's sci-fi detective story take off vertically and hover in the air like a Harrier Jump Jet.



DeLorean DMC-12, *Back To The Future Part II* (1989)

As if turning it into a time machine in the first film wasn't enough, Doc Brown upgrades his car for the sequel with technology from 2015, where all cars — and skateboards — fly.



Skyjet, *Valerian and the City of a Thousand Planets* (2017)

The Skyjet in Luc Besson's sci-fi epic can switch between urban and interstellar travel and was designed by real-life manufacturer Lexus.

"Uber is set to trial flying taxis in Dubai and Dallas"



Kitty Hawk are not currently planning to ship the Flyer outside of the US



Kitty Hawk set to make a splash

Less of a flying car and more of a hovering jet ski, the Kitty Hawk Flyer is a single-person ultralight aircraft powered by eight electric rotors. Backed by Google co-founder Larry Page, the Flyer travels up to 40 kilometres an hour and lifts up to 4.5 metres into the air. Like the jet ski, the Flyer is recreational rather than a main mode of transport, designed strictly for use over water. However, Kitty Hawk insist that it doesn't require a pilot's licence to fly and you can master the controls within hours. A price has yet to be confirmed, but Kitty Hawk plan to start selling the Flyer (with more aesthetically pleasing bodywork) by the end of the year.



"WHERE WE'RE GOING, WE DON'T NEED ROADS!"

The flying cars of the future will transform city infrastructure and, in turn, the way we live

Staying grounded

Having the option of driving or flying will enable people to still drive for short journeys, such as a trip to the local supermarket.

Flying in formation

Smarter onboard AI will allow flying cars to travel in close proximity (like a shoal of fish) to use airspace more efficiently.

"Kitty Hawk plan to start selling the Flyer by the end of the year"





On board the Dream Chaser

With the Space Shuttle in retirement, NASA is looking to the next generation of space planes

Sierra Nevada's Dream Chaser is a smaller, more adaptable version of the Space Shuttle and will spend much of its time going on trips to resupply the International Space Station (ISS). Unlike the Space Shuttle, Dream Chaser can fly autonomously, without a human pilot. Crewed versions will also be developed, capable of carrying seven astronauts plus cargo.

Once in space, it will be powered by twin hybrid rocket engines, which use two propellants – one solid, the other gaseous or liquid. These are mixed together and tend to be less explosive than purely solid rocket fuel when they fail. In the case of Dream Chaser, the solid propellant is a rubbery material called 'hydroxyl-terminated polybutadiene', while the gas propellant is

nitrous oxide. Its engines are so powerful that, when docked with the ISS, Dream Chaser can raise the Space Station's altitude, useful for avoiding pieces of space debris.

Dream Chaser is a fairly modest spacecraft in terms of size; its wingspan is seven metres, compared to the 23.8-metre wingspan of the Space Shuttle. It will be capable of carrying over five tons of cargo into space before returning to Earth hours later, landing like an airplane on a runway. Expected to first launch sometime in 2021–2022, there will be two versions; the Dream Chaser Cargo System sports folding wings to allow it to fit into the cargo fairing rockets such as the Ariane 5, while the crewed Dream Chaser Space System will launch on an Atlas V rocket to carry astronauts to the ISS.



The Dream Chaser will be able to return from space and land like an airplane



Compared to the giant Space Shuttles, Dream Chaser is modest in size

Spacecraft design



Mark Sirangelo, head of Sierra Nevada Corporation Space Systems, tells us more

"Dream Chaser is a pilot-automated space plane that has many similarities to the Space Shuttle. It is smaller in terms of overall size – it doesn't have the huge cargo compartment that the Shuttle did – but it has a similar sized pressurised crew compartment. This means that it can still take up the same number of astronauts (seven) and the same amount of protected cargo in the pressure hold as the Shuttle."

It's a highly reusable vehicle and, presuming that there's a mission and rocket, we can launch each Dream Chaser vehicle potentially five times a year. We're planning on having a fleet so that we can fly one while we're getting the next one ready to fly again. We are expecting our first orbital flight to be in [2021] but we're probably not going to have any crew on board to begin with."

© Sierra Nevada Corporation

What dreams are made of

Introducing one of the most sophisticated space vehicles ever built

Seven-strong crew

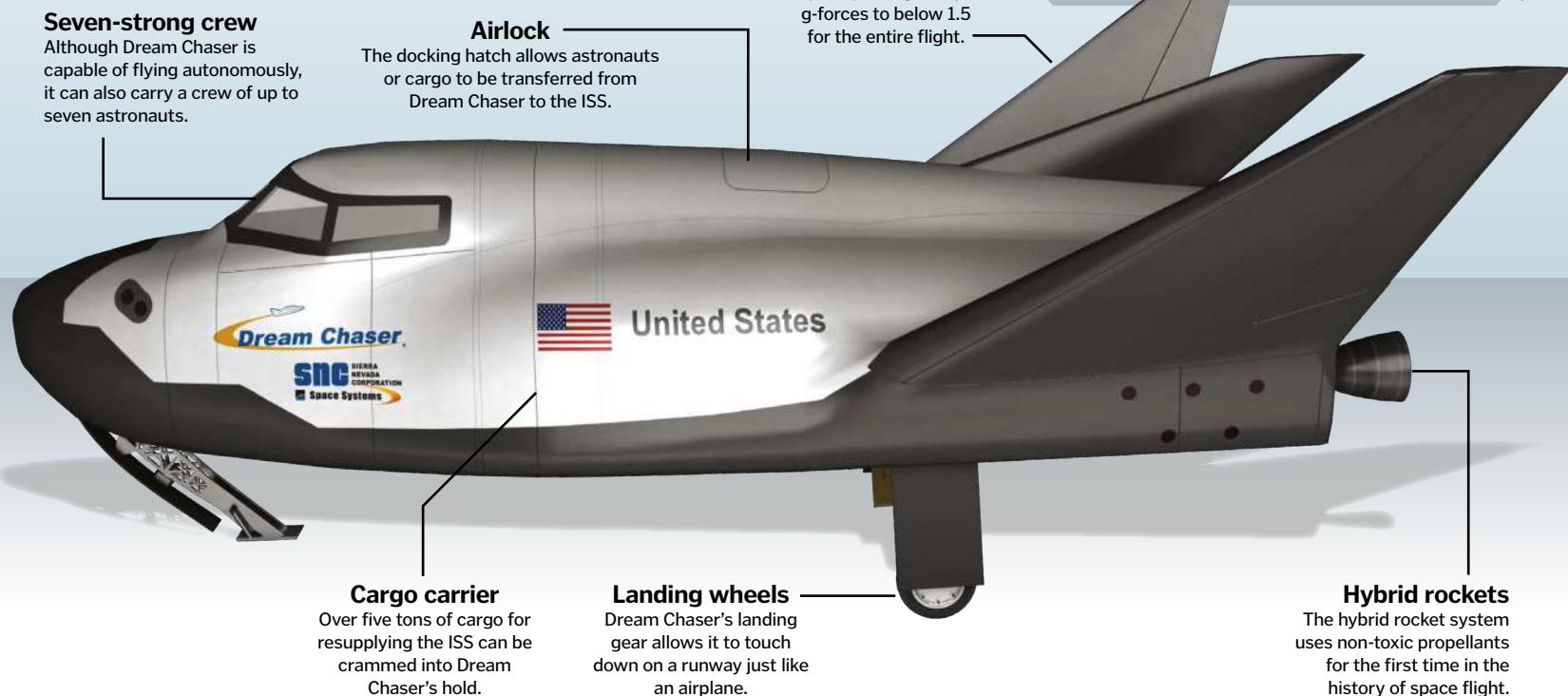
Although Dream Chaser is capable of flying autonomously, it can also carry a crew of up to seven astronauts.

Airlock

The docking hatch allows astronauts or cargo to be transferred from Dream Chaser to the ISS.

Wing profile

Dream Chaser's streamlined shape with upswept wings keeps g-forces to below 1.5 for the entire flight.



The rise of smart motorcycles

BMW has unveiled a high-tech bike concept that is impossible to topple over

Predicting a future where most vehicles will be driverless, BMW hopes to still provide bikers with a thrilling, hands-on ride. To celebrate its centenary year, the company has unveiled the Motorrad VISION NEXT 100 concept, a high-tech bike designed for the digitally connected world of the future.

While it may look a bit like something from *Tron*, the motorcycle does in fact take inspiration from a classic, as the black triangle frame is a subtle

reference to the R32, BMW's first ever motorcycle, released in 1923. However, this new upgrade has some rather more sophisticated features on board, including self-balancing technology. If the bike is about to tip over it will automatically right itself, even when stationary, meaning the rider won't fall off and can dismount without the need to flick out a stand.

Thanks to this safety feature, BMW doesn't foresee a need for riders to wear a helmet, instead

If the rider looks down while wearing the visor, a map of their route will appear

equipping them with a special visor that acts as a digital companion. If they look straight ahead, symbols suggesting their ideal banking angle and warning of any upcoming hazards will appear in their field of view, while if they look up, a rear-view function will activate, allowing them to see what's going on behind. The accompanying suit is also designed to enhance the riding experience, with a neck section that inflates for support when accelerating.

The BMW Motorrad VISION NEXT 100

The bike BMW thinks you'll be riding three decades from now

1. Flexible frame

With no bearings or joints, the entire frame adjusts with a turn of the handlebars, changing the direction of the bike.

2. Zero emissions

Designed to look like a traditional BMW boxer engine, the fully electric power unit extends outwards when the bike is in motion.

3. Visor display

As well as providing wind protection, the visor also features an information display, which can be controlled by the rider's eye movements.

4. Comfortable suit

The suit monitors the rider's body temperature, adjusting the level of heat accordingly, and vibrates to give navigation instructions.

5. Adaptive tyres

The variable tread of the tyres automatically adjusts to grip onto any road surface, whatever the conditions.

6. Modern materials

Under its matte-black fabric cover, the frame is made from carbon fibre, and so are the seat and wings.



More future vehicle concepts

The motorcycle isn't the only vehicle BMW has re-imagined for the future. As part of its VISION NEXT 100 exhibition, the company has also designed concepts for three of its car brands: MINI, Rolls Royce and BMW. The idea for the MINI is to have a network of cars available at all times, able to autonomously pick up drivers who can then adjust the car's appearance, driving characteristics and connectivity to suit their preferences.

The Rolls Royce, on the other hand, won't need a driver at all, as it will be controlled by a virtual personal assistant who can also fulfil your every wish throughout the journey. Customers will be able to create their own customised version of the car, which will be spacious enough for them to stand up inside.

The BMW combines the best of both worlds, allowing the driver to take the wheel themselves or hand over control if they want to sit back and relax.

BMW has also redesigned three of its cars for the future





We reveal the latest tech to help pursue lawbreakers, extinguish infernos and save lives

Maintaining law and order can be a tough test so having top-notch technology to back you up is essential. Both the current and upcoming generation of emergency vehicles contain state-of-the-art kit that performs a variety of functions, whether aiding in the pursuit of criminals, dampening flames or preserving life.

From unmanned drones, to futuristic ambulances and high performance police Interceptors, the technology at the disposal of the emergency services is extremely sophisticated. Take the Oshkosh Striker fire engine, for example, which can pierce up to 142 centimetres (56 inches) of metal in order to

access blazing infernos. Ambulances are also being revamped with the aim to kit out the vehicles with tools and apparatus that will be on par with the best a hospital can provide. Saving lives on the scene of an incident could become the norm in the near future.

Vehicles such as the Striker put efficiency and quality above everything else, while in Dubai police supercars are seen as the way forward. In the United Arab Emirates' largest city, everything is larger than life, and the police Lambos and Ferraris you see roaming the streets are no different.

Today's emergency services are also embracing less typical ways of maintaining order than

before. Unmanned aerial vehicles (UAVs) are already making an impact in the world of policing, allowing for new and effective ways of tracking offenders from the skies. The Stealth motorcycle is another vehicle that moves away from the traditional methods of policing by accessing both crowded areas and off-road locations with ease.

All of the emergency departments are finding ways to make the daily routine safer, simpler and more efficient. To see just how these new vehicles will revolutionise public safety, How It Works is getting under the bonnet of the emerging cars, trucks and bikes available to the emergency services. The future is now.

Inside an ambulance

How the ambulances of the world are the safest and best equipped they've ever been



The role of an ambulance isn't just to transport patients to hospital. Now, the vehicle must be capable of accessing remote areas and treating patients effectively on the go. Paramedics have the equipment to assess and treat the injured on the scene and while the vehicle is on the road. This gives the patient the best chance of survival even before entering the hospital ward.

Current ambulances come fully loaded with defibrillators and can administrate oxygen and monitor the heart. The wheels and suspension

have also been improved to allow off-road routes to be taken if there is congestion on the journey to the hospital. The LifeBot 5 is one device that has taken mobile healthcare that step further. Developed by the US Army, its motto is 'saving lives in real-time' and the telemedicine system comes equipped with a live link to a doctor in the nearest hospital. This allows the hospital to make more accurate assessments of the patient's condition and to prepare the ward for any surgery that may be required.

Despite all the modern upgrades, reaching the hospital in the quickest time is still the key objective. Today's vehicles come complete with a device that can change red traffic lights to green at certain intersections and use the best GPS and mapping systems available. These aids will prevent the motorist from driving recklessly and reduces shake and vibration from the road. This will enable more intricate and efficient treatments to be undertaken during the way to the hospital.

The modern ambulance

The medicines and equipment that paramedics have at their disposal

Medical supplies

All modern ambulances must contain everything a patient could need on a journey, from medicine to defibrillators to breathing apparatus.

Interior

The surfaces inside an ambulance are easy to clean for greater control of infection and spillage.

Stretcher

Stretchers are designed to comfortably transport the patient from the scene to hospital and can be wheeled or carried.



Chassis

Modern chassis are constructed be both light and manoeuvrable by using a lining of felt to dampen vibrations.

Law enforcement from the sky: Meet the police drones

UAVs or unmanned aerial vehicles have now spread their wings to the world of policing. Acting as the eye in the sky for police forces the world over, drones such as the Qube are rapidly becoming more and more important. Ready for flight in less than five minutes, the Qube can be dispatched quickly to track the whereabouts of a getaway vehicle or scout ahead prior to a raid or search. The bird's-eye view of a drone will give officers

an alternative viewpoint so they can respond to a distress call more efficiently and study evidence and forensics in more detail. With thermal-imaging capabilities, the Qube can be sent ahead to seek out criminals without putting lives at risk. UAVs usually operate at an altitude of between 30 and 150 metres (100 and 500 feet) but can also come closer to the ground and be utilised as a crowd-control device or in bomb disposal.





Future police cars

Meet the cars that will become part of an effective urban pursuit force

As well as looking sleek from the outside, the Interceptor is packed with state-of-the-art technology. The driver and passengers are protected by the sturdy Ford SPACE (Side Protection And Cabin Enhancement), which is both tough and comfortable. This system comes complete with a modern type of air bag that deploys between the passenger's head and the car window to give crucial protection in rollover collisions.

The Interceptor comes in two models: Sedan and Utility. Both are formidable adversaries to criminal activity with the Utility the slightly larger model that can carry more equipment and technology for longer, drawn-out pursuits. Both vehicles' drivetrain is ideally suited to 24-hour policing. The two turbochargers on board maximise acceleration and minimise

turbo lag, meaning there is no hesitation when responding to an emergency call. This is part of a high-pressure direct-injection fuel system that makes the award-winning Ford 3.5-litre EcoBoost engine as efficient as possible while producing 365 horsepower (272 kilowatts).

All this power would be pointless if it wasn't for the all-wheel-drive system (AWD) that upholds the Interceptor's handling at high speeds and in tough corners. Most cars in today's market boast good power and handling, so what does the Interceptor have that civilian cars don't? The answer lies in the 220-amp alternator on board. Essentially a huge power pack within the vehicle, it helps power all the gizmos an officer will require in a day's policing, including radios, computers, video cameras and radar.

Inside the Interceptor

Discover the tech that makes the Interceptor the way forward for police cars

Personal Safety System

Sensors operate the air bags so they can determine the size of a collision and distinguish between firefights and crashes.

Cooling system

An optimal amount of air flows through the car so it can cope with the heat generated during a typical day.



Structure and strength

Using safety-cell construction technology, the Interceptor has strategically placed crumple zones that absorb the energy of a crash.

Crash testing

The chassis of an Interceptor is so strong that it can pass a rear-end crash test at 120km/h (75mph) with flying colours.



The Ford Interceptor aims to meet the increasing demand for power and safety for law-enforcement vehicles

Engine

Using Ford's own EcoBoost technology, the car's 3.5l V6 engine produces 365bhp (272kW) and has two turbochargers to prevent lag.

Wheels

An Interceptor is designed to maintain law and order 24 hours a day with its high strength five-spoke steel wheels.

Dubai's supercar cops

Whether it's the tallest building in the world or an artificial archipelago shaped like a palm tree, Dubai doesn't trade in half measures. The police force is no different, with its supercars the envy of both petrolheads and other cops around the world. The fleet has everything from Lamborghini Aventadors to Bugatti Veyrons and Bentley Continentals. The Lamborghini is particularly impressive, boasting a top speed of 350 kilometres (217 miles) per hour in its 6.5-litre V12 engine. The cars are as much of a tourist attraction as they are a law-enforcement vehicle. Dubai isn't exactly a global hotbed for street crime and many onlookers feel it was just a publicity stunt for the 2020 World Expo, which the city was set to host. However, if a happy medium between performance and reliability can be found, the police cars of the future may not be all that different to the ones we currently see patrolling this modern city's streets.



Lawbreakers will have to pack some serious speed to out run Dubai's police force!

Green policing on two wheels

If an Interceptor isn't available, you can always hop on a motorcycle. As adept off road as it is on the streets, the Zero SP is quiet and exhaust free. Its electric powertrain gives it a top speed of 158 kilometres (98 miles) per hour and a range of 286 kilometres (178 miles) and it can recharge anywhere with a connection to the main grid. Its silence and lack of emissions mean the motorcycle can be used in tight situations such as compact city streets and dense pedestrian areas. Rather than go in all guns blazing, silent patrols offer an alternative solution to security and law enforcement. Its lightweight chassis and regenerative braking make it extremely manoeuvrable, allowing the bike to be inconspicuous and have the element of surprise when on the trail of a suspect. The Zero SP promotes a new way of policing that can undertake patrols effectively while being environmentally friendly at the same time.



The Zero SP is developed by Zero Motorcycles and promises an electric, exhaust-free way of policing



Doors

The ceramic ballistic front door panels help to protect the driver and front passenger by shielding them from bullets.

Braking system

The heavy-duty braking system has specially designed callipers that create an effective cooling system on the wheels.





Fire engines

The Oshkosh Striker is a rough, tough fire truck coming to an airport near you

Aviation fuel is extremely flammable so it is essential that a top-of-the-range fire engine is always on hand to fight the flames at airports across the globe. Enter the Oshkosh Striker. First produced in 2001, the vehicle had a bit of a revamp in 2010 and has now become the leading light in its class. Its combination of flame-smothering foam and quick acceleration make it a must at airports where smoke can choke a plane cabin in minutes. It has become so popular that it is used as the response vehicle of choice for US Air Force bases and even the White House.

The Striker's powerful foam and water cannons and a rapid response time make it a powerful all-round firefighting machine. To achieve maximum acceleration, engineers removed unnecessary parts and replaced heavy materials with lighter ones for more speed. Small but vital additions such as all-wheel suspension, a high reach extendable turret and an intercooled engine make it a match for the strongest of infernos. Its simple control system combined with its high-visibility windows make it easy to run and service so the vehicle is always available to fight fire.

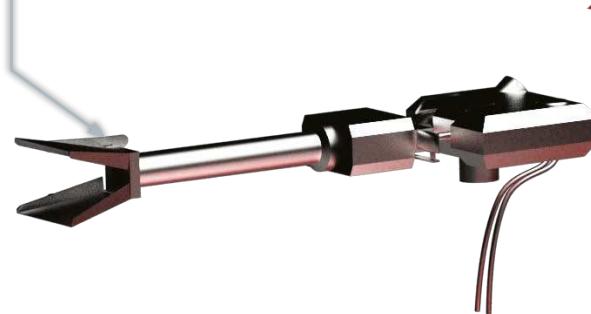
There are three different models of Striker: the 4x4, 6x6 and 8x8. Each one is larger and better equipped than the last, but all can be deployed to race down the runway in the face of an airport fire. With extra terminals springing up at airports worldwide and a constant stream of planes travelling through them, the Striker has never been in higher demand.

The Oshkosh Striker

US company Oshkosh has packed all its technological expertise into this monster of a fire engine

Hull-piercing cannon

There is the option to equip the Oshkosh with a 142cm (56in) long metal "Snozzle" to puncture the hull, allowing the foam to spray into the aircraft cabin.



Cab

Five people can clamber in but the Striker is so simple to use that it can be operated by one person.



Foaming agent

The Striker comes equipped with 1,590l (420ga) of foaming agent and 11,356l (3,000ga) of water to extinguish the toughest fires.

Firefighter protection

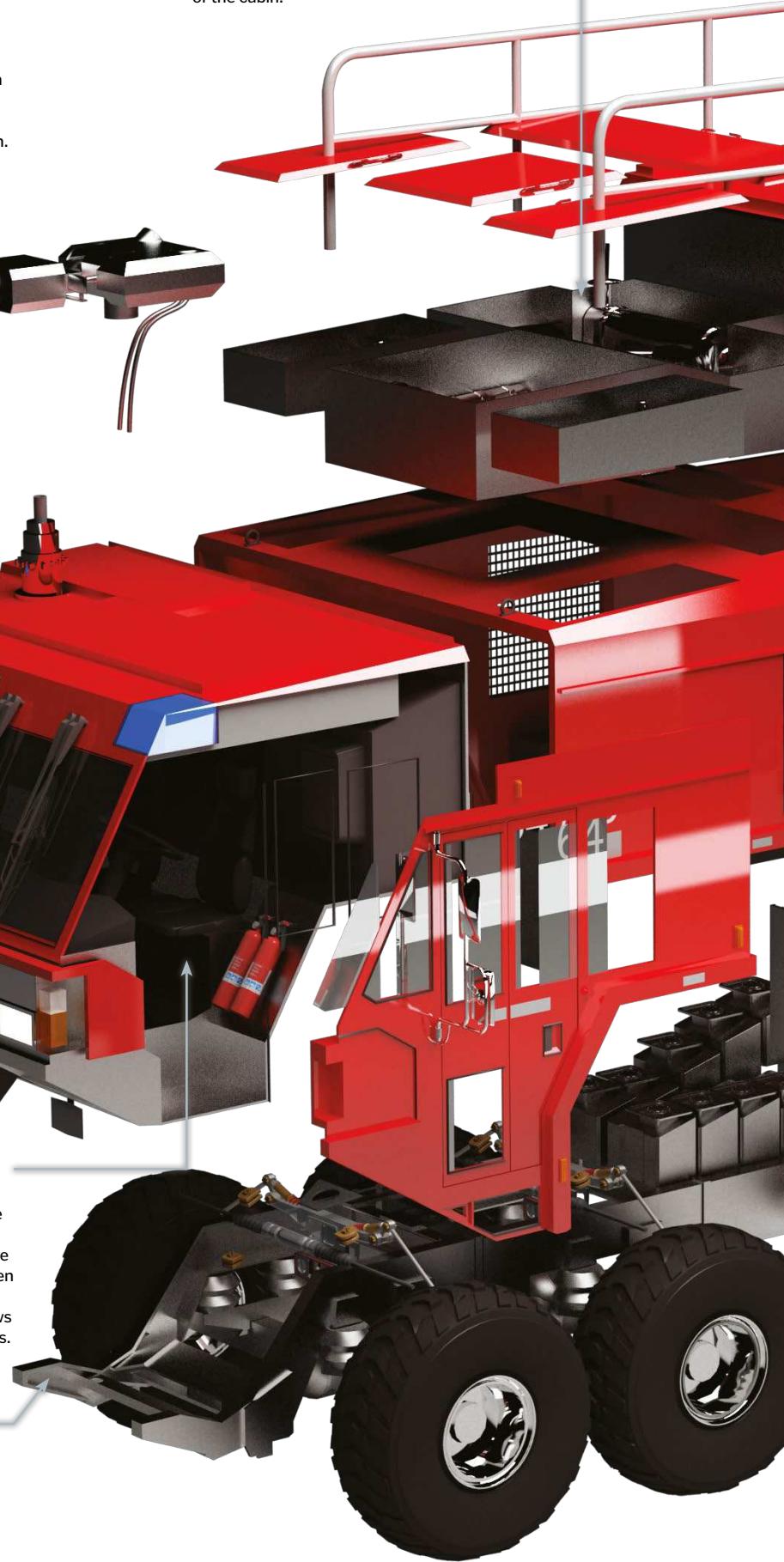
The crew inside are well protected by the glass windscreens that offer panoramic views of huge infernos.

Undertruck nozzles

Fuel spills are a common issue in airports so six undertruck nozzles have been attached to spray foam 360 degrees.

Cameras

To concentrate the water cannons on the epicentre of a fire, infrared cameras are used from the safety of the cabin.





Chemical tank

As well as foam, the Striker holds high amounts of potassium bicarbonate to prevent oxidising reactions in the fire.

Lightweight chassis

It may weigh 44 tons, but the Oshkosh doesn't hang about, as it is constructed out of custom-designed light materials.

Engine

The V8 engine powers both the drivetrain and the cannons and uses computers to adjust the power to different situations.

Hop on the electric, exhaust-free police motorcycle

Interview with Scot Harden, VP of Global Marketing for Zero Motorcycles



What was the inspiration behind Zero?

Our mission is to transform two-wheeled recreation and transportation through our innovative, high-tech motorcycles. We aspire to provide all the attributes you normally expect from the motorcycling experience, the sense of adventure, thrill, freedom and personal fulfilment without any of the hassles associated with motorcycles. No heat, no vibration, no emissions and no sound.

How will police forces around the world utilise it in their fleets?

Over 50 agencies in the US are using Zero motorcycles as well as several high-profile international police/security organisations, including Hong Kong and Colombia. Our motorcycles are used for routine patrol, crowd control, event and private security efforts. The stealth nature of our products allows authorities to arrive on the scene of criminal activity unannounced and to patrol areas otherwise inaccessible. The low maintenance costs provides additional motivation to adopt our products. Currently Zero-fleet motorcycles are being used by police, military, university campus, fire departments and private security forces.

What technology is used in the Zero?

We use a proprietary drive train that has been developed internally by Zero and features the most energy-dense battery system available today. Our ZForce powertrain consists of three main components; the motor, battery and controller. Battery technology is based on lithium-ion chemistry.



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LIFESTYLE & ENTERTAINMENT



074

The Martin Jetpack



064

Travel 2050



46

Future of food

What needs to be done to 3D print a pizza?

52

5G will change your life

How ultrafast mobile internet will enable new technology

60

How will we shop?

Shops will become more high tech to match online shopping

64

Travel 2050

Discover what your holiday will look like in the year 2050

70

The future of teaching

How will the education of our future generations change?

74

The Martin Jetpack

This private jetpack will be the answer to your commute

75

Flexible future of smartphones

Roll up your smartphone and simply put it in your pocket!



075

Flexible future



FUTURE OF FOOD

Why you'll be eating lab-grown burgers, 3D-printed pizzas & insects

In the year 2050, dining at your favourite restaurant is likely to be an altogether different experience. After being greeted by your robot waiter and taken to your table on a hoverboard, you will be left to peruse the holographic menu at your leisure. As you scroll through the options,

you'll notice that all of the usual dishes are still there, but with a few unusual twists thrown in.

For your starter, you'll tuck into a delicious Caesar salad containing protein-rich mealworms instead of chicken, and sprinkled with crunchy croutons made using cricket flour.



Creepy-crawly protein

Munching on mealworms and crickets is a healthier and more environmentally friendly alternative to eating beef or chicken.



Lab-grown meat

No animals need to be harmed in the making of your favourite meals, as scientists can grow meat from cells.

Genetically modified veg

Fruit and veggies can be tweaked to make them easier to grow, and more nutritious and tastier too.



Next, your android waiter 2.0 will bring over the mouth-watering main course; a meaty burger that has been grown in a Petri dish, garnished with crisp lettuce freshly picked from an underground farm and juicy tomato that has been genetically modified to contain extra vitamins. Then, if you still have room for dessert, you'll be able to choose from a range of sweet treats that have been designed on a computer and printed directly onto the plate.

These unconventional dishes may seem bizarre and perhaps stomach-churning to us now, but in the future they could help to solve a global food crisis. Over the next 35 years, the world's population is expected to exceed nine billion, meaning an extra two billion hungry mouths to feed. To fulfil this demand, the amount of food we grow will need to increase by 70 per cent, but with most of the planet's farmland already being used, and billions of its inhabitants already undernourished, this is going to be a major challenge.

Today's global food industry is already unsustainable, with agriculture responsible for almost a third of all human-caused greenhouse gas emissions. From the nitrous oxide given off by

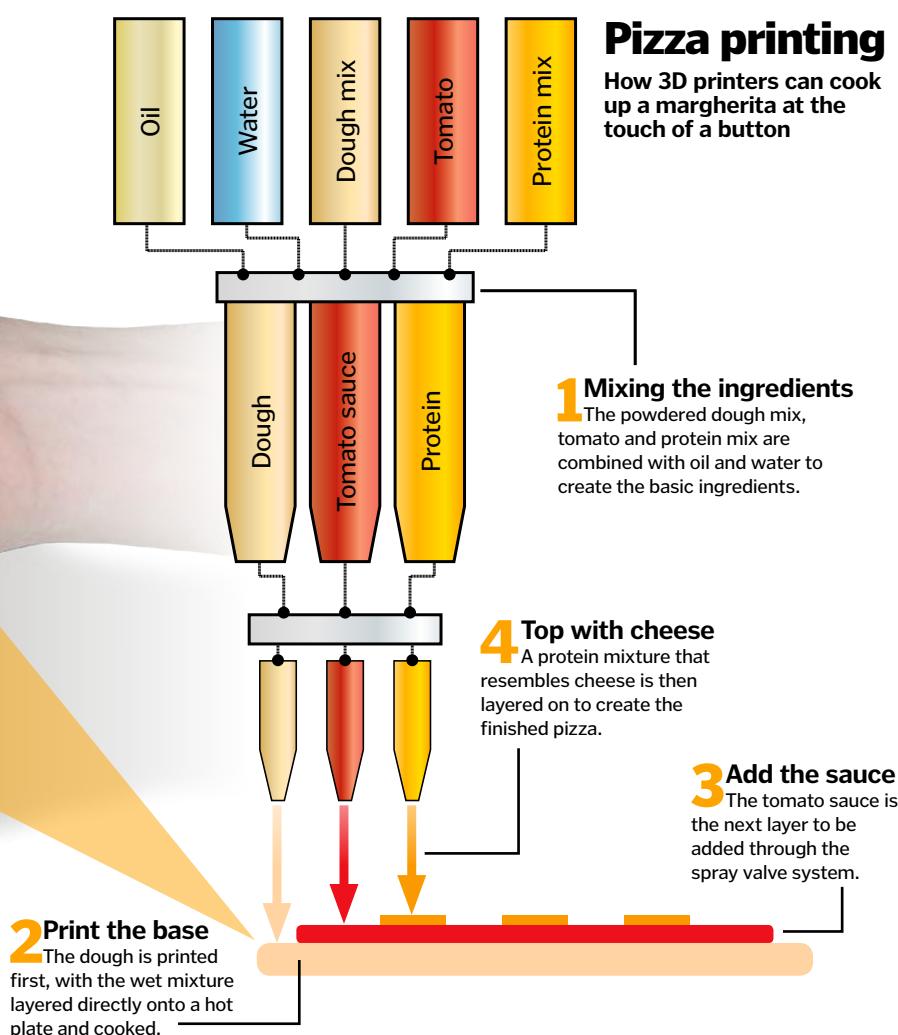
crop fertilisers, to the carbon dioxide generated as the produce is transported around the world, these gases are trapping heat in the atmosphere and gradually warming the surface. In turn, the changing climate makes it difficult to grow more crops, and so scientists will need to step in more and more to help. By genetically modifying the plants we grow, not only can the more vulnerable species be made able to withstand harsher, inhospitable environments, but the hardier species that can survive could also be made more nutritious to ensure we all get the vitamins and minerals we need.

Although growing fruit and vegetables generates a great deal of greenhouse gas, it is livestock production that is the biggest contributor to global emissions. It is estimated that producing one 230-gram (half-pound) hamburger generates the same amount of greenhouse gas as driving a typical passenger car for 16 kilometres (ten miles). Among these gasses is methane, which is about 25 times more effective at warming the planet than carbon dioxide. As demand for meat grows, so does the list of negative consequences for our planet, so something needs to be done very soon.

Of course, one simple solution to the problem is to eat less meat, but for a mostly carnivorous global population that gets through around 285 million tons of the stuff each year, this idea is unlikely to catch on. Therefore, tasty alternatives need to be found, and our idea of what we consider to be meat may need to change too. For example, the beef and chicken in your burgers and burritos could soon be swapped for crickets and locusts, or perhaps be grown in a lab instead of on a farm.

In fact, even traditional farms as we know them are likely to look completely different in just a few decades time. Gone will be the days of farmers having to drive tractors and milk the cows themselves, as autonomous machines are already starting to take over and make the industry more efficient.

Once these eco-friendly and sustainable foods have been harvested, we might not recognise the products that hit the shelves. Instead of packets and tins, your local supermarket will sell ingredients in cartridges that you can load into your 3D printer at home. Then, with a press of a button, you can sit back and relax while the machine builds a delicious dish – layer by layer – that is sure to impress your dinner party guests.



3D-printed meals

3D printing is already being used to create car parts, clothes and even prosthetics, but next on the agenda is your dinner. You will soon be able to make a meal from scratch simply by choosing a recipe and clicking print. 3D food printers that can produce intricate edible designs from sugar and chocolate already exist, but the Foodini, a 3D printer that can create a wide range of both savoury and sweet foods, is due to go on sale in 2016. Once you select your desired recipe, Foodini will tell you which ingredients to place into its food capsules, then it will start printing your dish in layers until it is ready for you to cook in the oven or pan. It can create crackers, pizzas, veggie burgers and even ravioli, allowing you to keep track of exactly what goes into your meal. As well as benefiting you at home, 3D printing food could also help to improve the quality and variety of meals available for astronauts on long duration space missions. A NASA-funded project has developed a machine that can print a pizza from dried ingredients with a 30-year shelf life, meaning it could someday feature on a menu on Mars.



Beijing Hesion 3D Technology is developing a pancake-printing machine, to satisfy those creative sweet treat cravings



Lab-grown meat

Discover how scientists can create burgers without harming cows

Global demand for meat is expected to increase by more than two-thirds in the next 40 years, and we are already struggling to cope. Current methods for producing meat are not very sustainable, as huge amounts of land and other resources are needed to rear livestock. As these assets get harder to come by, the price of meat will continue to rise, meaning that it could soon become an unaffordable luxury. The meat industry is also having a negative environmental impact on the planet, with the animals releasing huge amounts of methane, a greenhouse gas that contributes to global warming.

Many scientists believe the solution to this looming problem is cultured meat grown in the lab, and a team from Maastricht University in the Netherlands has already perfected the technique. By extracting stem cells from a living cow they have been able to grow muscle tissue and turn it into a burger that tastes a lot like the real thing. The cells taken from just one cow could produce 175 million burgers, which would normally require meat from 440,000 cows; better still, the animal remains unharmed. It's not just beef that can be grown this way either, as the method can easily be replicated to create chicken, pork and other meats too.

Before you start planning your lab-grown barbecue though, scientists believe it could be another ten to 20 years before the meat becomes commercially available. It currently costs around €250,000 (£185,000 or \$280,000) to produce a single burger, but as the method is refined, cultured meat could become cheaper than the conventional kind grown on farms by 2035.

The cheese and meat in an Impossible Burger are made entirely from plants



How to build a burger

Turning plants into beef

If a lab-grown burger doesn't get your mouth watering, then maybe one made entirely from plants will. Impossible Foods has discovered a way to make meat and cheese without animals, yet still promise that it will 'delight' and nourish the most discerning meat lover.

From plants such as greens, grains and beans, they extract proteins that have a meaty texture, flavour or aroma. The proteins are then mixed with amino acids,

vitamins and fats – also from plants – to create the three main components of meat; muscle, connective tissue and fat. When these are combined in the right proportions, they form a burger that looks, tastes and smells just like ground beef. The Impossible Burgers are already available in four restaurants in the US, and will be followed by a range of other meats and dairy products, all made entirely from plants.

1 Harvest the tissue

A sample of muscle tissue is harvested from the cow in a harmless procedure and cut into tiny pieces so the muscle fibres and cells can be separated.



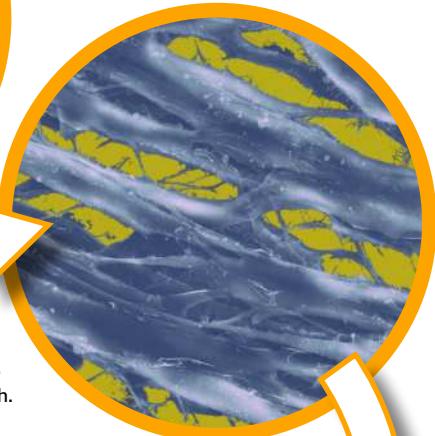
2 Nurture the cells

Individual muscle cells are removed and nurtured in the lab. Each one divides multiple times to produce many more cells.



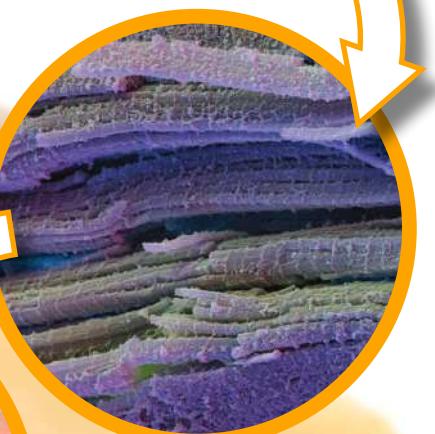
3 Form muscle fibres

The cells naturally merge together to form myotubes – developing muscle fibres that are less than 0.3mm (0.01in) in length.



4 Add some bulk

The myotubes are placed in a ring and begin to put on bulk, growing into a small strand of muscle tissue.



5 Layer the tissue

It takes approximately 20,000 of these strands layered together to form a normal sized burger.



The insect diet

People throughout Africa and Asia regularly eat bugs as a source of protein, but these creepy crawlies could soon catch on in the Western world, too. The United Nations' Food and Agriculture Organization has suggested that insects are a healthier, more environmentally friendly and more sustainable alternative to conventional meat, and insect farms are already popping up across the world.

Although they might not seem appetising, many insects are very nutritious, containing lots of good

fats, calcium, iron and zinc. Rearing them also requires much less land than traditional meat production and results in considerably fewer greenhouse gas emissions.

As they are cold-blooded, insects are much more efficient at converting food into protein, with cows needing 12 times as much food as crickets to produce the same amount of protein. They can also be fed on food scraps and animal manure to help recycle waste.

The Micronutris insect farm in France breeds many species of insect for human consumption



Farms of tomorrow

How technology will help farmers cope with increasing demand

With more and more mouths to feed, farms need to be run as efficiently as possible in order to keep up with demand. As a result, many farmers are turning to new technologies for help, using precision systems to make many of their day-to-day tasks easier.

For example, GPS is already widely used to ensure tractors are driven in straight lines across fields, preventing them from overlapping their routes. This helps to save fuel, fertiliser and seed that would otherwise be wasted as the farmer covers the same piece of land again and again. However, in the not-so-distant future, farmers may not need to drive their tractors at all, with several self-driving machines currently in development. Other farming machinery is also becoming increasingly hi-tech, with robots being used to feed and milk livestock more efficiently.

Although some of this cutting-edge tech is unaffordable for many farmers at the moment, the farms of the future are likely to be incredibly large-scale businesses, which need to be almost entirely automated in order to be cost-effective. So instead of mucking out the pigs and feeding the cows, future farmers will be able to sit back and let the machines do all the hard work, while they control everything from their smartphone or tablet.



Going underground

An abandoned World War II bomb shelter may seem like an unusual location for growing vegetables and herbs, but subterranean farms could be the future of crop growing. With conventional farmland becoming more and more scarce, and crops at risk from changing weather, indoor alternatives can be used to fulfil the demand and provide a more controllable growing environment. To grow plants indoors, hydroponic systems can be used. Instead of soil, the plants sit

in trays of water enriched with nutrients, while banks of LEDs overhead provide light for energy.

The Growing Underground farm 30 metres (100 feet) beneath the streets of London uses a controlled hydroponics system to grow crops all year round, and can deliver its produce to the city's restaurants and wholesalers within just four hours of being harvested. As only green energy is used to power the lights, the farm is also carbon-neutral.



Growing Underground has turned an abandoned bomb shelter into a sustainable farm



"GPS is already widely used to ensure tractors are driven in straight lines"

Automated milking machines

Robot milking machines allow cows to be milked whenever they want, so the farmer doesn't have to herd them up at 5am. The machine knows which cow is which and automatically attaches the milking teats when they enter the booth.

Robot livestock feeders

Automated feed pushers can sweep the livestock's feed towards them when they are lined up at the feed fence, ensuring that they have a constant supply of food and giving the farmer one less back-breaking task to do.

Aerial drones

Drones can be used to produce accurate maps of farmland to calculate fertiliser needs, give farmers a bird's eye view of their land to help them monitor crops and even scare away pests before they can damage the yield.

Farm management software

Tech-savvy farmers can manage many aspects of their farm from their computer, using software to map their land, calculate the resources they need and monitor their livestock. This can help decrease wastage and boost productivity, making the business more profitable.

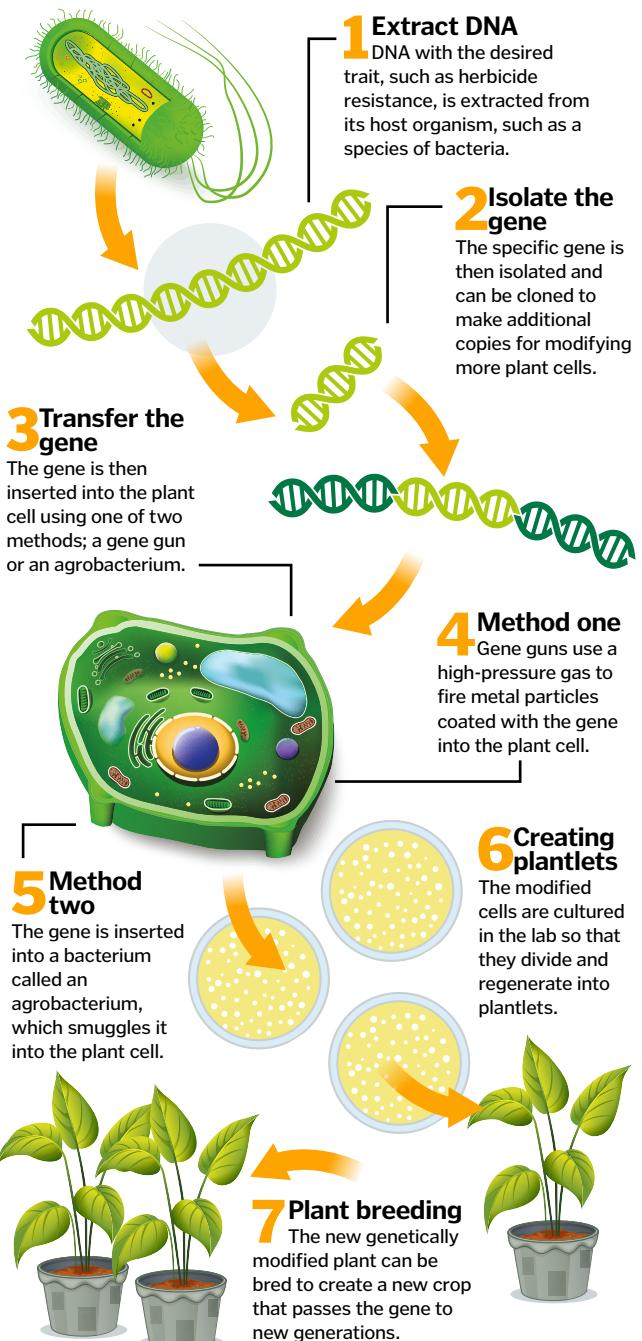


Genetically modified crops

Growing enough food for the rapidly growing population of a planet with a changing climate would be more or less impossible without genetic engineering. By modifying the genes of plants, new crops can be created that are resistant to weed-killing herbicides and disease-causing pests, or are able to grow in inhospitable conditions. These genetically modified organisms (GMOs) can also be created to produce fruit and vegetables that stay ripe for longer, reducing wastage, or even contain more of the vitamins we need to stay healthy. Although there is some controversy surrounding GMOs, there is currently no evidence that they are bad for your health; people and livestock have been consuming them for decades with no ill effects.

How to genetically modify a plant

The simple steps for creating a modified food crop





5G



HOW IT WILL SUPERCHARGE YOUR LIFE

THIS ULTRAFAST MOBILE INTERNET TAPS INTO UNTouched FREQUENCIES, ENABLING TECHNOLOGY THAT WILL TRANSFORM HOW WE LIVE AND WORK

Look at the top-left or top-right corner of your phone screen. What does it say? The chances are it reads '4G'. If you visit a city, this might change to '4G LTE'. This means you'll get slightly faster internet. Or if you travel to the countryside, it could say '3G'. Here your video streaming might stutter. But now, if you're in the right place with the right device, that top corner will say something new: 5G. And nothing will be the same again.

The 'G' stands for 'generation'. 5G is the fifth generation of mobile connectivity, combining pioneering research and the latest technology. But this new generation of network will change more than just how we use our mobile phones. "It will have the same impact as electricity, silicon and steam had in the previous industry revolutions," says Åsa Tamsons, the head of new

businesses at Swedish telecom equipment maker Ericsson.

What makes 5G different from previous generations is that it works over higher radio frequencies. While all radio waves travel at the same speed, the wavelength of a particular frequency directly affects how fast it can transmit data. As a rule of thumb, the higher the frequency, the shorter its wavelength and the more bandwidth it has to send information.

The highest frequency 4G uses is 2.6 gigahertz (GHz). The 5G phone towers that are being turned on right now transmit between 3.5GHz and 6GHz. This is why 5G can offer download speeds of up to ten gigabits per second (Gb/s) – ten times what 4G could ever achieve. This will enable you to wirelessly download HD movies in seconds, not minutes.



5G's speed will enable AR and VR to be widely used in hospitals

Of course, high-speed mobile internet isn't just about downloads. There's also latency. This is the communication delay on the network, the time lag between you sending a command – tapping a button on a webpage, for example – and the site responding. The less time it takes, the lower the latency. While 4G had a maximum latency of 50 milliseconds, 5G reduces that to just four milliseconds, giving you a near-instantaneous connection every time.

But in the next few years, 5G could get even faster, as internet providers plan to tap into the frequencies way beyond 6GHz. The part of the spectrum between 30GHz and 300GHz is known as the millimetre band for its extremely short wavelengths – just 1-10mm wide. These so-called 'millimetre waves' (or 'mmWaves') have been used for radio astronomy and radar guns in the

past. Once we start using mmWaves' blazing-fast bandwidth, 5G will stop feeling like good Wi-Fi and will deliver the benefits it promises.

However, higher frequencies come at a cost. The short wavelengths can't travel long distances and are easily disrupted. Millimetre waves, in particular, require a line of sight with the device they're sending data to and can be blocked by walls or even rain. We'll have to build more antennas in our towns and cities so that we're always close enough to pick up a signal. However, higher frequencies only need small antennas, so rather than high phone towers looming over cityscapes, transmitters will be built into lampposts and traffic lights.

These days, mobile networks aren't just about phone calls. We now have all sorts of bandwidth-demanding devices: tablets that

Mini data centres

Rather than transfer data back and forth to server farms kilometres away, internet providers will build mini data centres into 5G towers to further speed up local data processing.

Innovative infrastructure

The next-gen network is so new, telecoms companies are still experimenting with different ways of delivering it



Indoor antennas

As mmWaves can't pass through concrete, transmitters may even have to be built inside buildings.

Enhanced phone towers

Initially, existing 4G phone towers will be upgraded to use higher frequencies (excluding mmWaves) and offer increased bandwidth.

Swarms of 'small cells'

As 5G can only transmit over short distances, cities will be filled with lots of miniature masts, built into lampposts and traffic lights.

Traffic jams could be consigned to history with 5G networks managing roads



"Rather than high phone towers looming over cityscapes, transmitters will be built into lampposts and traffic lights"



Not just an urban boon, 5G will benefit rural businesses and communities too



5G will enable people to work and stay connected on the go far more easily

Zapping users with data beams

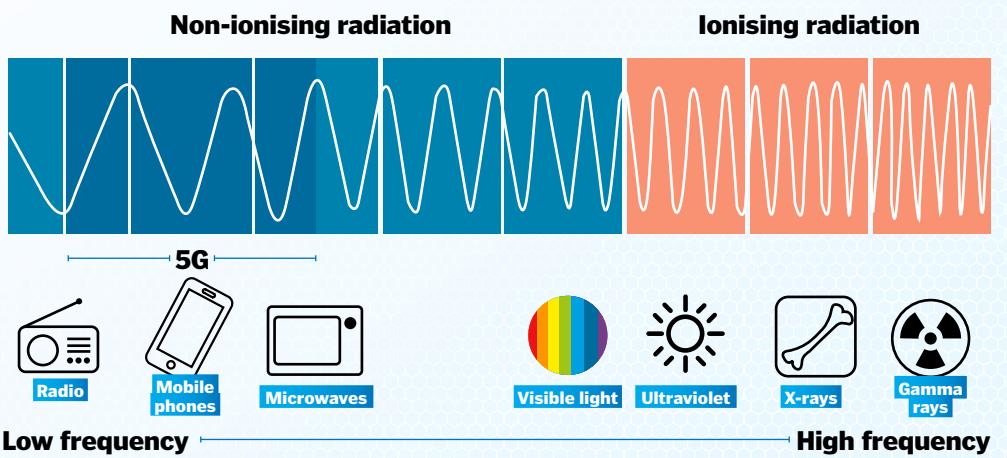
The higher the frequency, the smaller the antenna you need to detect it. This means you can cram many more into a handset or mast. These can then work together in an array to form a focussed beam of data. Called 'multiple input, multiple output' (MIMO), arrays like this actually already exist. They are used with the faster-than-normal 4G known as LTE. But due to the size of antennas these lower frequencies require, only two or four can fit on both the mast and device. In contrast, it's been estimated that 256 millimetre-wave antennas could be fitted to a phone tower. This jump in scale will be a game-changer. A mega MIMO would be powerful enough to precisely target beams at individual devices. Much more energy-efficient than transmitting a signal across an entire frequency, this would help overcome 5G's biggest weaknesses, allowing signals to cover much larger distances.



A 5G MIMO antenna on display in Shanghai earlier this year

Where does 5G sit on the EM spectrum?

The electromagnetic (EM) spectrum describes all wavelengths, including the visible light we can see and many we can't, like microwaves and x-rays. Radio waves sit at the non-ionising end, with the lowest frequencies and longest wavelengths. Dangerous gamma rays sit at the ionising end, with the highest frequencies and shortest wavelengths, which can damage DNA and cause cancer. While 5G uses higher frequencies than 4G – including millimetre waves – these remain within the 3kHz to 300 GHz radio wave band.



Everyday 5G

While it'll take time for the network to reach its top speeds, 5G will have instant benefits (if you live in the right place)

More energy efficient

Smart software will give telecoms companies better control over networks, so they can make sure there's always enough bandwidth and the system uses less power.

Better business

By having a much faster and more reliable network, businesses – big and small – are expected to benefit hugely from 5G: a 2017 report by PSB Research stated that 89 per cent of businesses expected their productivity to increase.

Smarter classrooms

Augmented reality and virtual reality lessons will be available to students in a 5G-enabled schools, and teachers could deliver lessons remotely in real time, lag-free.

Driving autonomous vehicles

The network will be able to send autonomous vehicles all the data they need – perhaps from smart city road sensors – at a speed that's quick enough to respond to sudden changes, such as a person walking out in the road.

Better connections in crowds

With support for up to 1 million devices per square kilometre, 5G's capacity means a more reliable experience – even in the busiest places at the busiest times.

More reliable

Signals will transfer between phone masts in less than a single millisecond, with no drop-outs.

Forget loading times

A maximum latency of just four milliseconds means you'll always get what feels like an instantaneous internet connection.

Superfast downloads

With up to ten times faster speeds, 5G means quicker downloads and the best-quality video stream, every time.

connect to the cloud so people can work on the go, smartwatches that have their own data plans and household gadgets like always-on HD security cameras. This trend is expected to continue, with the world going from 8.4 billion internet-connected devices two years ago to over 20 billion by 2020 – tripling the amount of mobile data we use.

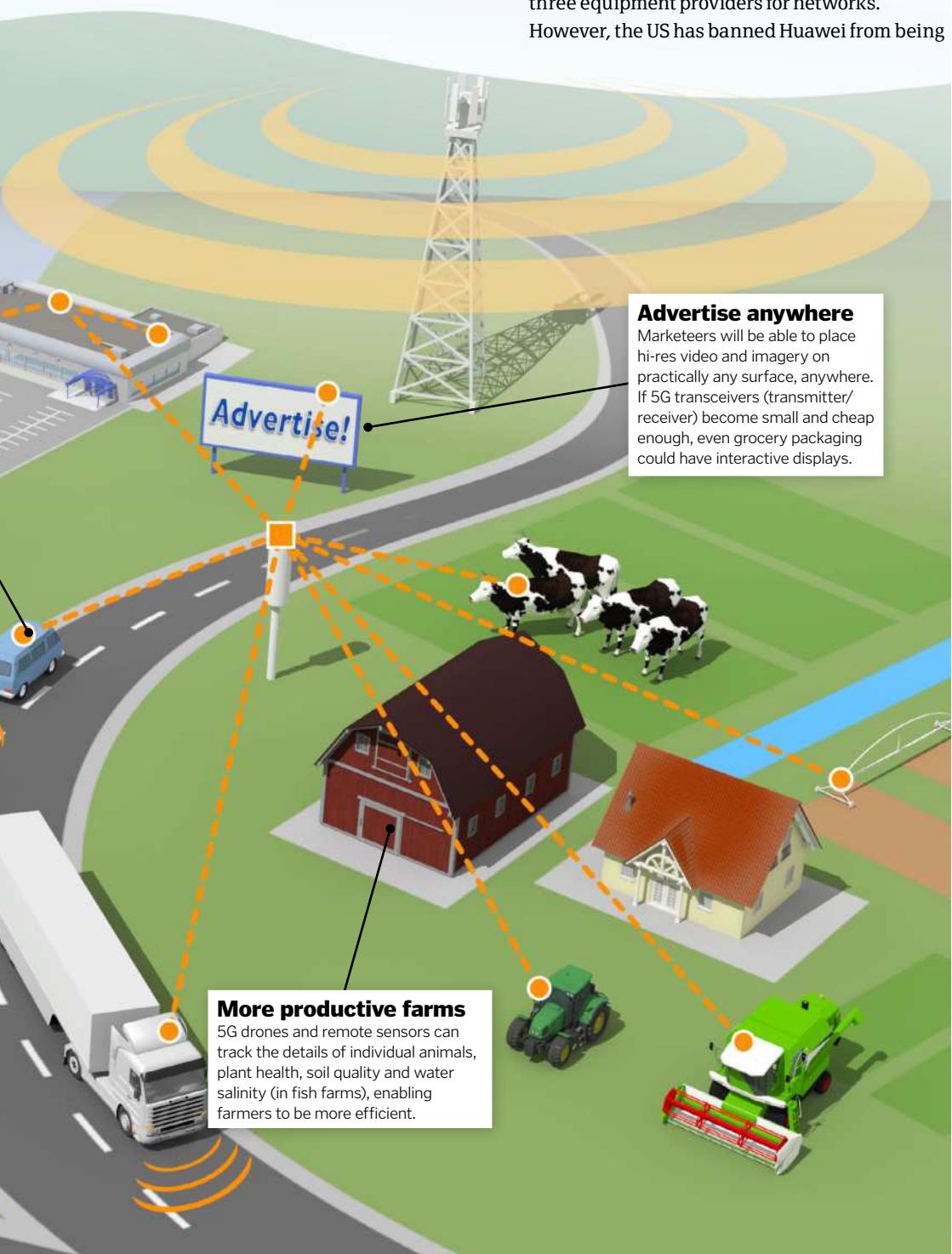
Fortunately, 5G is up to the job. The shorter wavelengths it uses also give it more capacity, meaning the network can handle more information at one time. So while 4G could connect 100,000 devices per square kilometre, the next-gen network will handle 1 million.

Not only is this high capacity future-proof, but it will set the so-called 'internet of things' (IoT)

into hyperdrive. Thousands of everyday objects – from your home to your work to the street corner – will be fitted with sensors, collecting, transmitting and sharing data. All of this information can be combined and analysed in the cloud, helping homes, businesses and whole communities make smarter decisions.

This technological leap forward will lead to new products, businesses and even industries, from self-driving cars to artificial intelligence. Experts say 5G could drive an extra \$12 trillion of annual sales by 2035. That's about the size of China's entire economy. It's perhaps no surprise then that countries, as well as companies, are racing to embrace 5G.

The first step is to get the infrastructure in place. Nokia, Ericsson and Huawei are the top three equipment providers for networks. However, the US has banned Huawei from being



Q&A

Is 5G hazardous to your health?

Dr David Robert Grimes, cancer researcher and physicist, discusses fears over 5G

The UN's International Agency for Research on Cancer (IARC) has classified radio frequency radiation (RFR) – which includes mobile signals – as "possibly carcinogenic". Should we be worried?

This isn't especially worrying, oddly enough. IARC classification is based on the strength of evidence for a particular agent having a cancer risk, not the degree of severity of that risk. RFR is classed as 2B, which effectively means there's no reliable evidence that there's any cancer risk associated with it. IARC's system is ripe for confusion, so it's understandable this classification can worry the unwary.

Is there any evidence suggesting mobile phones are linked to tumours?

There really isn't. Firstly, from a biophysics perspective, the radio frequency of radiation used in mobile phones is strictly non-ionising, so we wouldn't expect it to be able to cause the kind of DNA damage that leads to cancer. Secondly, despite rates of phone use going from almost nothing to high-on 100 per cent in just over two decades, we're not seeing any evidence of increased brain tumours, which is what you'd expect to see if there was an effect, as we hold phones to our ears for long stints. To take one example of many, the 13-country Interphone study observed no increase in the risk of common brain cancers correlated with phone use. There is simply no epidemiological data that phones are linked to tumours.

5G requires hundreds of transmitter masts, positioned closer to ground level. Does this mean they'll be giving off more radiation?

Not at all. 5G needs more transmitters because it's more easily attenuated by the environment and can't travel as far. To overcome this, you need more transmitters... but it doesn't mean they'll be giving off more radiation.

Why do you think 5G health risks have prompted conspiracy theories?

Anxiety over 5G isn't unique – we've seen similar unfounded panics in the past on everything from vaccination to water fluoridation to mobiles. What's difficult to address is the fact misinformation can perpetuate further and faster than ever before, allowing scaremongering stories to spread.



involved in certain networks, amid allegations its equipment could be used to help Chinese spying. It's a charge the company strenuously denies. Australia has followed the US's lead. Germany is now tightening up its law on telecoms security standards, but the UK has said it's still willing to work with Huawei.

South Korea was the first to roll out 5G nationwide, with all of its leading telecoms companies switching on their new networks in April. Despite being significantly larger, both China and the US aimed to achieve the same thing in 2020. Up to 25 cities in the UK were promised 5G by the end of the year, with the first six in May. Switzerland, though, was leading the pack in Europe, rolling out 5G in 227 areas.

Next will come the phones. 5G will need a next-gen modem, so older phones won't support the new speeds. Many top phone makers have committed to making (or have launched) 5G smartphones. These include Apple, Samsung, Huawei, OnePlus, LG, Xiaomi and Oppo.

Initially, 5G will be targeted at businesses, but this will ultimately benefit all of us. Faster speeds and lower latency for businesses will mean faster responses and better services for consumers. The 5G future is coming along faster than you expect.

Goodbye broadband?

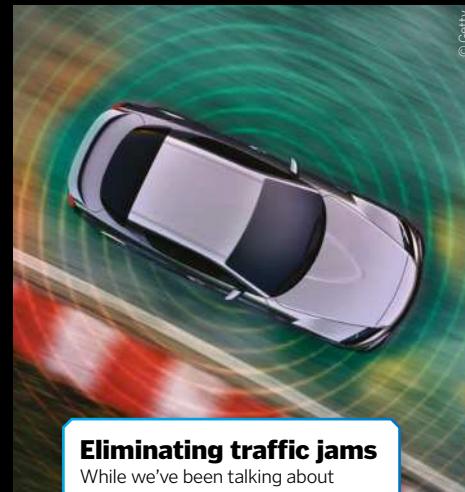
With 5G, mobile internet promises to beat home broadband speeds, so is it time to cut the cord? You'd have one less bill to pay and it'd be easier to install. Engineers wouldn't need to dig up roads or drill holes in walls to connect homes. Mobile network Three certainly thinks so. It's already selling 5G home routers to do just that, starting in London. You simply plug these into the wall to start accessing up to 100Mb/s speeds. However, established broadband providers think fibre still has a future. They're developing a 'network of networks': smart software that automatically switches you between 4G, 5G and Wi-Fi, depending on which signal is stronger or has more capacity at peak times, so your internet experience is never interrupted.



5G could enhance or ultimately replace your home internet

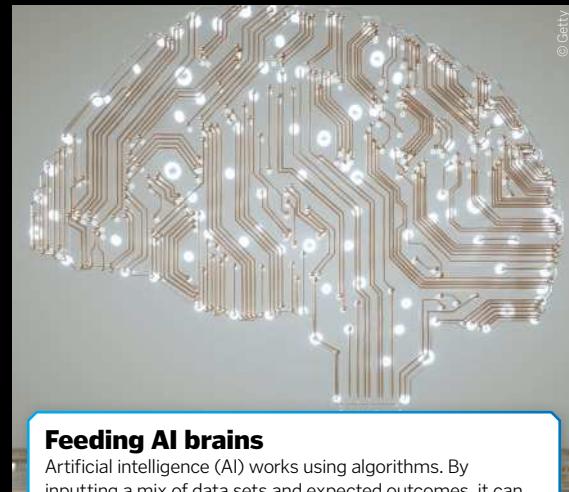
The future of 5G

How 5G will be utilised by businesses and communities



Eliminating traffic jams

While we've been talking about self-driving cars for years, they might finally hit the road with 5G. In the future, autonomous vehicles could be the norm, with traffic managed entirely by 5G systems that can make traffic jams a thing of the past.



Feeding AI brains

Artificial intelligence (AI) works using algorithms. By inputting a mix of data sets and expected outcomes, it can learn to spot patterns. The more data you feed it, the smarter it gets. And 5G will create a massive amount of data. AI may even ultimately manage 5G's incredibly complex networks.



Making drone deliveries

Just as 5G will allow self-driving cars to steer themselves, this technology can do the same for drones, providing them with information, so they can zoom above our heads. This will lead to superhighways in the sky filled with parcel delivery drones and possibly unmanned flying taxis.

The evolution of mobile networks



1940

Also called 'OG', the first 'mobile radio telephones' are more like walkie-talkies – only allowing two-way communication – and fill a whole suitcase.



1979

Launching in Japan, 1G allows users to make calls on the go. The phones are chunky, with limited battery, and the signal is poor.
Max speed: 2.4Kb/s



1990

2G's big improvement is to switch from analogue to digital, improving the call quality and making it possible to send data.
Max speed: 64Kb/s



1992

The world's first text message is sent in the UK, reading 'Merry Christmas', from software developer Neil Papworth to his Vodafone boss, Richard Jarvis.



5 FACTS ABOUT WHAT TO EXPECT FROM 5G PHONES

1 Antennas all over

As millimetre waves are easily disrupted, phones will have to be built in a way so that hands don't cover up the receiver at any time. One solution is to stash tiny antenna arrays in every corner.

2 Longer-lasting batteries

For now, switching between 5G and 4G might drain your battery. But as coverage expands and phones are fitted with more efficient 5G modems, you can actually expect to get something of an energy boost.

3 Bigger price tags

These superfast smartphones will be expensive initially, as will phone plans. But the price will drop over time – just like it did with the launch of 4G.

4 Android only – for now

Samsung, Xiaomi and OnePlus are all selling 5G versions of their flagship handsets. Meanwhile, experts don't expect Apple to launch a 5G iPhone until next year.

5 8K cameras

Chinese smartphone maker Nubia already sells a phone that shoots 48-megapixel pictures and 8K video, so with more bandwidth to play with, it's hard to imagine this trend not catching on.



Remote-control surgery

In March, a Chinese brain surgeon operated on a patient 3,000km away. Guiding a robotic arm, 5G's near-instantaneous connection meant the machine responded in real time to the surgeon's instructions. So-called 'telesurgery' – which allows leading specialists to help wherever they are – will become increasingly popular.

Making AR a reality

Imagine a world where everything looks like a Snapchat filter, overlaid with moving holograms. With increased capacity and lower latency, 5G will make both augmented reality (AR) and virtual reality (VR) more lifelike. Smart glasses can offer next-gen gaming and immersive entertainment on the go.

Building smarter cities

Just as homes are getting more hi-tech – with internet-connected locks, thermostats, lightbulbs and more – so are cities. Sensors connected via 5G will measure everything from a city's energy usage to road traffic to air quality, helping communities make more informed decisions, be safer and better organised.

1998
Finland's Radiolinja launches the first downloadable content sold for mobile phones: the ringtone. These beeping jingles become hugely popular worldwide.

2001
Mobile phones go online with 3G. It isn't that fast, but you can surf the web, send emails, stream music and even make video calls.
Max speed: 2Mb/s

2007
The first iPhone launches. Though it is criticised for not offering 3G, the touchscreen device shows how smart the new 'smartphones' can be.
Max speed: 100Mb/s

2009
Debuting in Norway and Sweden, 4G is ten times faster. It makes HD video streaming, gaming and cloud computing possible.
Max speed: 100Mb/s

2018
In December, 3GPP – the organisation that manages mobile standards – agrees what spectrum 5G will use, giving the telecoms industry the green light.
Max speed: 1Gb/s

2019
South Korea is the first country to roll out 5G nationwide in April, with the rest of the world not very far behind.
Max speed: 1+Gb/s



How will we shop?

From robot shop assistants to virtual fitting rooms, this tech will revolutionise retail

There is no doubt that the internet has changed the way we shop, with many people preferring to click and buy from the comfort of their own homes instead of venturing out to browse the local stores. The convenience of not having to deal with bustling queues or lug your purchases around is no doubt very appealing, but there are huge benefits for the retailers too.

As people peruse their products online, companies can collect lots of useful data about

them by way of cookies. These simple text files are downloaded onto your computer when you visit a website and store information about which products you looked at there. The cookies can then be accessed by the retail company, enabling them to target you with adverts based on your preferences, so you will be more likely to take notice. This personalised service often helps to boost sales, but it isn't something the stores on the high street can take advantage of.



With many stores struggling to compete, some clever innovators are developing new technologies that can help them. The Dandy Lab, a menswear and lifestyle outlet in London, is providing a testing ground, enabling companies to try out their ideas on real-life

Lighting the way How Philips' system can help you navigate the aisles



1 Emit the signal

When you enter the store, the light fixture above you emits a unique identification code.



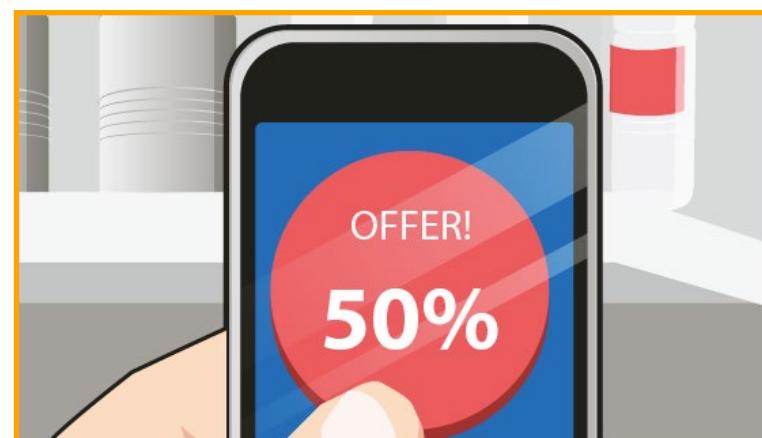
2 Find your location

Your smartphone's camera receives the code telling it exactly where you are in the store.



3 Plan a route

An app on your phone plots the most efficient route to the products on your shopping list.



4 Get the deals

As you walk down an aisle, the lights above send discount codes for the nearby products to your phone.

customers. "At the moment there is a lot of tech for online shops, but there is nothing really happening in the brick and mortar environment," says co-founder Julija Bainiaksina. "We wanted to see how we can integrate technology in-store and make the shopping journey from online to offline seamless and more convenient for the customer."

The 'clothes-store meets retail technology lab' is currently trialling several new methods for enhancing the shopping experience. These include smart mannequins that can send information about the clothes they are wearing to the customers' phones, and a mobile payment app that enables you to use your phone to scan a product's barcode, pay for it and take it home without having to queue at all. The shop is also attempting to replicate online 'cookie' technology with a smart loyalty card scheme that helps shop assistants provide a more personalised service. "We give every single customer a loyalty card containing an RFID [radio-frequency identification] chip, and at the door we have an RFID reader," says Julija. "Once the customer comes back to the shop, we instantly receive information about what they bought, what they like and so on. This gives our sales staff a better understanding of the customer, so they can recommend products based on their previous purchases."

For Julija, using this new technology is not about competing with online retailers but helping online and offline shopping to complement each other. "For physical shops, the main benefit is the ability to showcase their products and provide an experience," she explains. "What we found out is that a lot of people come to the shop just to try on the products, touch them, feel them, and see if they really want them, and then they go home and buy them online. Alternatively, they might do research online, and then come into the shop to try something on and buy it. So both of those channels – online and offline – need to work with each other. The technology should somehow fuse them together to provide one seamless shopping experience for the customer."

In the future, it could be that shops simply become showrooms, stocking tester products for you to try before you purchase them via interactive display screens. Alternatively you may not need to visit the shop at all, instead using a virtual reality helmet to browse and even interact with the products before you part with your cash. In the meantime though, there are plenty of changes already appearing on the high street. From Bluetooth beacons that help you bag a bargain to augmented reality mirrors that let you try on clothes without getting changed; a trip to the mall is about to get a lot more high-tech.

"Smart mannequins can send information about the clothes they are wearing to the customers' phones"

Virtual reality shopping

Imagine being able to wander around a shop and try out the products without ever leaving your house. With several virtual reality headsets now available, this fantasy is fast becoming reality, enabling you to experience the fun of shopping without the stress of crowds or queues. It can also open up some unique try-before-you-buy opportunities. Teaming up with Microsoft Hololens, car manufacturer Volvo was able to create a virtual showroom, allowing customers to strip down holograms of its cars and watch the vehicles in action. Virtual reality production company Visualise has also made it possible for customers of travel agent Thomas Cook to experience holiday destinations before booking a trip.



The growth of virtual reality will enable you to explore shops from the comfort of your home



Volvo's virtual reality showroom lets customers see the inner workings of its cars

Beacon bargains

Everyone loves a bargain, and thanks to a new retail technology, they are becoming easier than ever to find. Devices called beacons are small Bluetooth transmitters that can be installed in shops and communicate with smartphones of passers-by. Already being used on London's Regent Street, the beacons can send exclusive deals to an app on your phone when you walk past a shop, encouraging you to step inside and snap up the offer.

While these beacons can detect when you are nearby, Philips' connected lighting system has taken things even further. The LED lights it has installed along the aisles of a Carrefour supermarket in Lille, France, can work out exactly where you are in the store, and send deals for products in close proximity. The technology is called Visible Light Communication, which uses rapidly flickering LEDs to emit signals that are picked up by your smartphone's camera sensor.



Beacons installed in 'smart mannequins' can tell you exactly what they are wearing

Illustrations by Edward Crooks





The mall of 2050

The high-tech breakthroughs that will change the way you shop

Sensors and trackers

Knowing more about the people who walk into their store can help retailers provide personalised customer service. However, instead of using intrusive facial recognition, Hoxton Analytics has developed a footfall counter that gathers data from people's shoes. A camera records their feet as they walk into the store, and a processor uses clever algorithms to determine their likely age, gender and what brands they like. Other sensors can also track the Wi-Fi pings from customer's smartphones to track where they look in the store.

Information screens

With shops only capable of stocking so many products, some are already including digital displays that let customers access the entire catalogue if they can't find what they want in-store. In the future this could lead to virtual stores, such as the experiment by South Korean store Homeplus. Images of their products were displayed on the walls of a subway station, and by scanning a QR code on their phone commuters could order online and have them delivered by the time they got home.



QUAY

GIGI

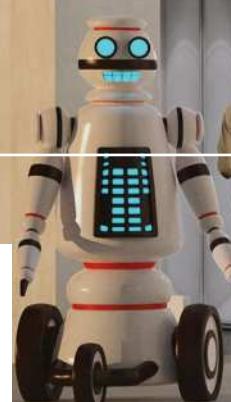


3D printers

As well as selling 3D-printed products, some stores are already letting you print your own. A variety of 3D-printing stores have already started to pop up on the high street and could be a staple of shopping malls in the near future. Customers will be able to download a design or create their own. They can then have the product made while they wait or send their design to the shop and pick up the finished product later.

Virtual fitting rooms

Instead of having to get changed to try on a new outfit, images of the new clothes can be superimposed over live footage of you on the fitting room 'mirror'. The Magic Mirror uses a Kinect body sensor to monitor your position so it can ensure correct placement of the garment on a screen. You can then select a new outfit via gesture or touch screen control, and even take a picture of your new look to send to your friends for approval.

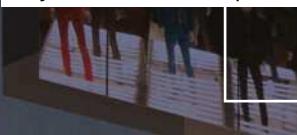


SIDE

Fashion

Smart tags

Tags on your clothes could soon tell you a lot more than the washing instructions. As electronic components have become smaller and cheaper, Norwegian company Thinfilm have been able to develop flexible smart labels with Near Field Communication technology, enabling a wide range of useful information about the product to be sent to your smartphone. This could alert you to ingredients in food items that you might be allergic to, or tell you more about how a product was made.



Robot shop assistants

With so many different products in a store, it can be difficult for the staff to know where everything is. This is why researchers at Carnegie Mellon University have developed AndyVision, a robot that can patrol and scan the aisles to create an interactive store map for customers. It can also perform an inventory to alert staff when a product is low in stock or if an item is out of place on the shelves.



"3D-printing stores have already started to pop up on the high street"

Digital window displays

Researchers at the Massachusetts Institute of Technology have developed see-through screens that could replace shop windows. Nanoparticles embedded in the material can be tuned to scatter only certain wavelengths of light, letting the rest pass through so the screen appears transparent. This would enable additional product information and adverts to appear over physical window displays – this could then be changed depending on the weather, time of day or even who is walking past the store at the time.

Boutique



Drone deliveries

If you've done your shopping but don't fancy carrying it home or waiting ages for it to be delivered, you could get it sent to your home by a drone. At the moment, delivery drones such as Amazon's Prime Air are only allowed to be flown within sight of the operator, but as computer power improves and sensors become cheaper, automated flying will become much safer.



TRAVEL 2050

YOUR TICKET TO THE HIGH- TECH HOLIDAY OF THE FUTURE



It's 2050 and taking a vacation is easier than ever, thanks to the latest technological breakthroughs. Over the next few pages, we'll guide you through every step of your trip, from planning and booking, to travelling and making the most of your stay.

Some of the technology involved might seem unbelievable, but all of it was already real, or under development, in 2021. Take the process of booking your trip; you may have been using comparison websites to find the best deals, but now you don't need to enter your information, as online travel agents already know your preferences. Gareth Williams, CEO and co-founder of travel company Skyscanner, said: "Travel search and booking will be as easy as buying a book on Amazon."

There's no longer any guesswork involved in picking your holiday destination either, as Nik Gupter,

Skyscanner's director of hotels, already predicted back in 2016: "In ten years' time a traveller will be able to take a virtual reality walk through the hotel he is planning to book in real-time."

The stress of travelling is long gone and getting to your destination is almost as enjoyable as the holiday itself. In 2016, Melissa Weigel from design studio Moment Factory said: "In the near future, airports will be an intrinsic part of the holiday experience." Since then, automated check-in and speedy security scanning has made boarding your flight a breeze.

Holiday destinations have also changed a great deal, as futurist Daniel Burrus predicted: "Relatively affordable trips in low Earth orbit that enable you to experience a few minutes of weightlessness will happen very soon." Now we've our sights on the Moon and Mars.

CHOOSE YOUR MODE OF TRANSPORT



Dassault Systèmes' concept for a flying cruise liner



The Spike S-512 jet will mirror the speed of Concorde



Avoid the airport altogether by taking your TF-X flying car



The 90-metre luxury JAZZ yacht features an indoor pool

BOOKING YOUR HOLIDAY

Get the VIP treatment from the off

Choose a destination

Social media and online retailers use members' profiles to monitor activity and alter the content they see. Travel brands now operate in a similar way, logging your likes and dislikes, while facial coding algorithms, as developed by Affectiva, enable search engines to read human expressions and gauge how happy you are with the results.

IN DEVELOPMENT



Take a virtual vacation

VR headsets enable you to try before you buy. By using dual lenses with a slightly different image in front of each eye, it recreates your normal stereoscopic vision and fools your brain into thinking virtual worlds are real. Disney's Revel system, developed in 2012, uses electrical signals to create the feeling of touch.

Smart tags

As you drop off your bags, they're fitted with tags containing Near Field Communication (NFC) chips. When they come into close contact with another NFC chip inside the scanner, your personal and flight data is transferred wirelessly. You can then track each scan via an app.

IN DEVELOPMENT

Biometric scans

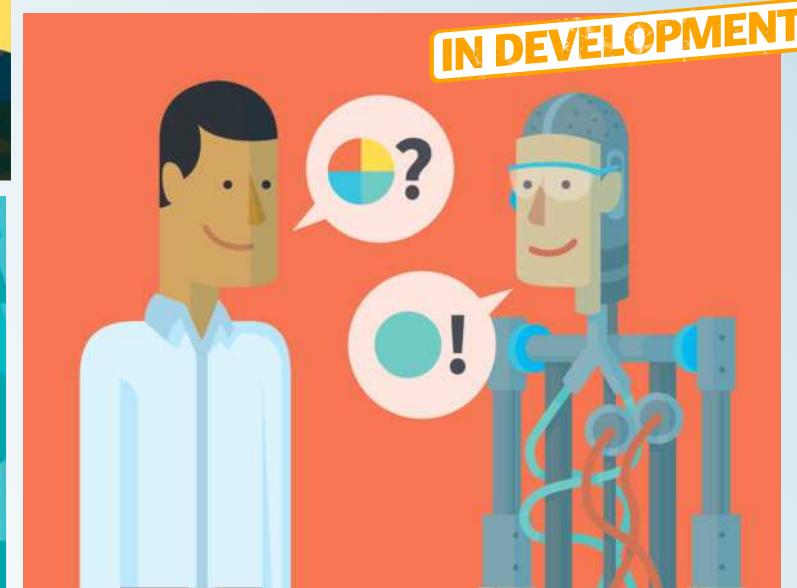
Instead of a passport, a biometric data card is used to identify you. Images of your eye, taken with a camera that records visible and infrared light, capture the exact position of the iris' unique patterns and features. As you board the plane, your eyes are scanned and matched.

IN DEVELOPMENT

Use an e-agent

You can rent an artificially intelligent e-agent from your local travel company to help plan your trip. The tech is similar to JIBO – the personal assistant released in 2015 that uses two hi-res cameras to recognise faces and algorithms to learn your preferences and adapt.

IN DEVELOPMENT



IN DEVELOPMENT



Book with ease

While apps like Expedia enabled 2021 holidaymakers to arrange most aspects of their trip, 2050 takes the tech a step further. You can use a one-stop app to book your flights, hotel and holiday activities with a couple of taps of your smartwatch. Even transport to the airport will be taken care of.

AT THE AIRPORT

How tech will take the stress out of travelling



Speedy checks

The Picosecond Programmable Laser is a scanner that vibrates the molecules in your body and possessions to identify different substances, from traces of gunpowder to the contents of your stomach. It's 10 million times faster than a conventional scanner.





ON THE PLANE

Your journey will fly by as you explore the onboard entertainment options

Instead of waiting around at the gate, you are free to explore the airport's rooftop gardens, art exhibitions and shops at your leisure, safe in the knowledge that a 3D holographic assistant will appear to tell you when the plane is boarding.

Holograms have been around since the development of lasers in the 1960s, but recent advancements in technology mean they're now much more impressive. They used to be created by splitting a laser beam in two and directing each beam towards an object using mirrors. The beams were then reflected off the object and at the point where they recombined, a still hologram of the original object formed. In recent years, we've mastered moving holographic images, resulting in ultra-realistic 3D content for entertainment and practical uses.

When it's time to stroll onto the plane, you'll find that the Airbus Concept Cabin has become reality, and you're no longer confined to your own seat. First class and economy have been replaced with zones tailored to your different needs, whether you want to relax, mingle with other passengers or play some games.

Sit back, relax and fly CONCEPT

Skyscanner's personalised aircraft seat concept will provide ultimate comfort on your journey

Smart lighting

Red wavelengths of light stimulate the brain's production of the sleep hormone melatonin, helping you drift off and fight jetlag.

Constant connection

Next-gen 5G mobile internet and advanced satellite broadband are available throughout the flight.

Sonic disruptors

Devices embedded in the seat rest prevent other passengers from hearing your private conversations.

Holographic hub

Hold 3D conversations with friends and family back home or become fully immersed in the movies of your choice.

Climate control

Built-in climate control lets you monitor and adjust heating and cooling systems for your individual seat.

Memory-foam seat

The roomy aircraft seat moulds to your body shape, providing comfortable support that minimises back pain.

CONCEPT

Modular aircraft

A cabin design with zones for work, rest and play

Immersive entertainment

Practise your tennis or golf at the virtual gaming wall or put on a VR headset to be transported to a cinematic world.

Interactive window displays provide interesting information about the view



Relaxing atmosphere

Soft aromas and gentle sounds fill the cabin to help ease you into a deep sleep.

Private pods

Pop-up rooms allow you to hold business meetings, have a romantic meal or read the kids a bedtime story on the flight.

Panoramic views

With the wave of a hand, the aircraft wall becomes transparent, offering a spectacular view of the outside world.

Self-cleaning

Dirt repellent coatings inspired by nature ensure the aircraft's fittings and furnishings are kept in good condition.

YOU HAVE REACHED YOUR DESTINATION

The smart hotel room will ensure the stress-free experience continues

Once you've stepped off the plane and swiftly passed through immigration with your biometric card, you will find another driverless taxi waiting to take you to your hotel. Instead of having to pick up your room key at the check-in desk, you can proceed straight to your room and unlock it using your smartphone, a system that was adopted early by Hilton and Marriott hotel chains.

Your bags are delivered to your door by a robot butler, such as Botlr, the droid employed by Aloft Hotels at their Californian establishments. He can be summoned via an app to bring you any toiletries you may have forgotten to pack, or deliver a tasty snack to help you refuel after your long journey.

Just as everything in your own home is connected to the internet, all of your hotel room's appliances are smart and intuitive too. You can even upload your home temperature preferences to the room's Nest thermostat, and display family photos on the digital wall displays, to help you feel really at home.

A good night's rest is guaranteed as the Sleep Number x12 bed features sensors that monitor your sleep, ensuring the alarm clock gently wakes you at the optimum time, and can tilt the pillows to stop your partner snoring. All of this tech already existed as of 2021, but has since been adopted by hotels throughout the world.



WEIRD HOTELS THAT ACTUALLY EXIST



The frozen hotel
Made entirely from 'snice' – a mixture of snow and ice – the Icehotel in Sweden melts in the summer and is rebuilt every winter, with construction taking just six weeks. Temperatures inside the hotel are between -5 and -7 degrees Celsius.



The salt palace
Located on the edge of the world's largest salt flats in Bolivia, the Palacio de Sal has been built using one million blocks of salt and features 16 rooms, a spa and a golf course. Everything from the walls to the beds is made entirely from salt.



The jumbo experience
If you haven't had enough of airplanes by the time you leave the airport, then Jumbo Stay will let you dwell in one too. The converted 747-200 jumbo jet is grounded near Arlanda Airport in Sweden and features over 30 rooms.



At the spaceport **IN DEVELOPMENT**

Catch a space plane into orbit from your local spaceflight hub

Airspace

Space plane operations are conducted in segregated special-use airspace, away from normal air traffic routes.

Remote location

Due to the higher risk involved with rocket vehicles, spaceports are located away from densely populated areas.

Spaceflight operators

Lots of different commercial spaceflight companies operate from the same spaceport, so a number of different vehicles are catered for.

Runway

Space planes like Virgin Galactic's SpaceShipTwo need a long runway for horizontal take-off and landing.

Terminal building

Not just for check-in and shopping, the terminal also hosts astronaut training facilities to prepare passengers for their flight.

Refuelling

Rocket engines need both fuel and a source of oxygen, and different types are needed for different spacecrafts.



World View's helium-filled balloon will float a capsule full of space tourists to the edge of space



SPACE TOURISM

Take a trip that's literally out of this world

If you really want to escape from it all, then how about leaving the planet altogether? Space tourism is a billion dollar market in 2050 and there are several companies offering trips. Blue Origin, the company set up by Amazon founder Jeff Bezos, can offer you breathtaking views from its New Shepard spacecraft as you soar over 100 kilometres above Earth.

You'll need to arrive at the desert launch site in West Texas two days before your flight so you can begin your astronaut training. You'll receive mission and vehicle overviews, in-depth safety briefings and instructions on how to move in a weightless environment. When the morning of your flight arrives, it's time to scale the steps of the launch tower and climb through the hatch of the capsule, which sits on top of an 18-metre tall rocket.

Once you're strapped in and have received final clearance for launch, the countdown to lift-off will begin. The extreme acceleration will

force you back into your seat and you'll experience over 3 g for 150 seconds and then the booster engine will cut off as you glide into space. The capsule will separate from the booster, and from the serene silence will come the signal to release your harness.

As you float out of your seat and marvel at the weightless freedom, you'll forget that you're travelling faster than Mach 3 – three times the speed of sound – and stare back at Earth out of the capsule window. Before descent, you will return to your seat to strap in for re-entry. Forces of over 5 g will push against you before the parachutes deploy and thrusters fire, reducing your speed as you gently float back to Earth. Once you've landed, just miles from where you launched, you can go and collect the complimentary souvenirs of your thrilling trip. That's right; novelty keyrings still exist in 2050.

Blue Origin first vertically landed a booster in 2015, paving the way for reusable rockets



XCOR Aerospace is planning to launch its Lynx spaceplane from its Curaçao spaceport



UNDERWATER HOTELS

Sleep, eat and relax with the fishes

Back in 2021, the closest thing to an underwater suite was the five-star Atlantis, The Palm, in Dubai. The floor-to-ceiling views of a colossal aquarium created such a spectacular illusion that celebs like Kim Kardashian West were willing to splash the cash to stay there.

But while a fully-fledged underwater haven like the Water Discus Hotel was just a concept

in 2021, its doors are open in Dubai in 2050. Once you arrive by boat or helicopter from the shore, you can relax in your room and watch the marine critters swim by, or sign up for a diving course to get even closer to the action. You don't even need to go back up to the surface in order to get in the water, as there's sea access direct from the underwater disc.



Underwater suites at The Palm, Dubai, offer views of 65,000 marine animals

CONCEPT

The Water Discus

Get up close with marine life in Dubai's ocean hotel





THE FUTURE OF TEACHING

WHAT WILL SCHOOLS BE LIKE IN 2050?



The modern-day classroom isn't really all that different from a Victorian classroom. The teacher still stands at the front, with the children facing them, answering questions and taking hand-written notes. While there isn't a cane, and we've swapped squeaky chalk for marker pens, the format hasn't really evolved.

It's strange when you consider the advancements that we've made in the same amount of time: we've landed on the Moon, unravelled the human genome and created super-computers you carry in your pocket. So why is education stuck in the 20th century?

In some schools, it isn't; advancements in teaching, communication and technology have totally changed the working environments of students around the world, and the future only holds more progress. Looking closer at that modern day classroom reveals some details you may have missed at the first pass. Those handwritten notes might be taken on an iPad with a stylus, with the handwriting converted into typed text and the finished document saved to the 'cloud'. The board is interactive, and can display websites, videos and more that the teacher can control with a smart remote.

In fact, while the basic format of teaching may remain largely unchanged, technology has improved how kids learn, what they learn, and how they are taught. Textbooks are, of course, still a big part of the school experience, but increasingly e-books and online research are being used in place of the traditional tomes. In some schools, students are loaned iPads or other tablets, loaded with their entire reading list for the year. Rather than straining their spines by carrying huge backpacks, pupils only need one device. Even better, they can make helpful notes on the pages, or highlight useful sections, without being charged for defacing the book.

Of course, these books can also include links to websites that aid learning. Digital pages can contain useful information for additional study or homework, or can even take students to online tests. The teacher can then check in on who has taken the test, how they scored, and get more information about each pupil, including how long they spent working on each question.

The internet has become a valuable teaching resource and is regularly used in the classroom. Rather than formal videos recorded in the days of VHS, teachers can quickly find useful resources and play them to the class. Not only is this more engaging than a video that's decades old, it can also prompt further discussion.

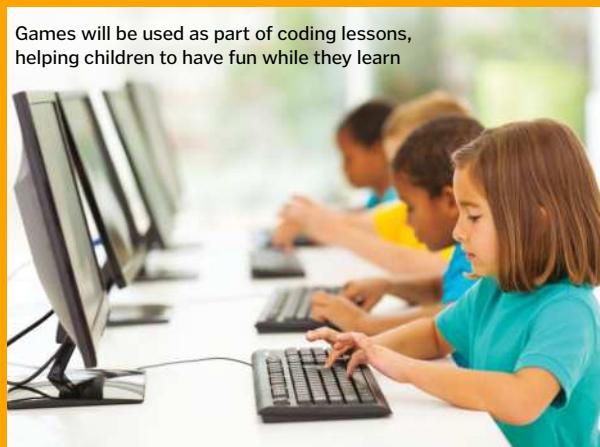
Technological advancements have changed the way teachers work, too. More and more, students are being encouraged to work in small groups and foster interaction, with technology as an enabler. Learning spaces are being



The idea of every student having a tablet won't seem odd in ten years

TABLETS OVER TEXTBOOKS

In the coming years, the idea of carrying around piles and piles of heavy books for each school day will likely be a thing of the past. Whether it's schools providing their pupils with tablets, or students bringing in their own computer devices, the future of the textbook is clearly in a touchscreen display. A single tablet can hold an entire year's worth of learning materials, as well as providing students with interactive tests, videos and apps, controlled by the school. In some schools in the US, this is already happening, and it's undoubtedly the first step in a teaching revolution.



Games will be used as part of coding lessons, helping children to have fun while they learn

GAMING AND LEARNING

Many teachers and parents assume video games are unnecessarily violent and highly addictive, and without educational merit. But in recent years games have started making their way into the classroom as learning materials. Games like Minecraft, which now has a dedicated Education Edition, can teach children through play. And kids who usually go home and spend hours of their free time on games like this are enjoying learning more than ever. Using games in the classroom will only increase as coding lessons become more commonplace in the near future.



Virtual reality will let students take trips through history and into space

VIRTUAL REALITY LESSONS

Soon, classes won't need to leave the school to take a field trip. Virtual reality headsets will allow students to journey across the world, and even dive beneath the waves or float through space, without ever leaving the room. As this technology becomes more affordable and software developers begin to create virtual learning spaces, lessons will become more engaging and immersive than ever before. Pupils could soon find themselves learning about volcanoes from the edge of Mount Etna, exploring ancient dig sites in Egypt, or even taking a trip through the human body to study anatomy.

redesigned to reflect this, and teachers' roles are slowly changing to a more passive role.

And as technology becomes more and more accessible, this will only increase. Tech like 3D printing will allow students and teachers alike to create teaching materials within minutes. 3D modelling lessons will be able to go from the design to the prototyping stage within a few hours, while lessons about biology will see teachers printing out 3D models of ancient animal skulls to pass around the class. Cloud computing will eradicate excuses like "the dog ate my homework", and give classmates a chance

to discuss their work at home, using teacher-controller chatrooms that allow them to collaborate on projects. Gaming will increasingly be used to teach, and eye-tracking will help teachers analyse what works best in the classroom, and what is failing to grab attention.

Of course, as teaching changes, so will the curriculum. For example, as computing skills are becoming more important in this digital age, many students are learning how to program. In the UK, pupils as young as five are being taught how to code, with simple games showing them the basics.



FUTURE CLASSROOMS

How will tech change learning in the coming years?

Indoor school trips
Students will bring in their own VR headsets from home in order to take virtual outings as a group.

Online discussions
The online area will be used as a place to communicate, with students and teachers contributing to discussions about a day's lesson for homework.

Guided learning
Interactive boards will allow teachers to pose questions at the start of the lesson, before students form into groups to direct their own learning.

Desk-embedded computing
Desks will be a lot more than surfaces to lean on. Screens built into the table-tops will allow students to work without extra computers or hardware.

Digital worksheets
Paper-thin screens will be commonplace, allowing a single worksheet to change throughout the day to display information the students need.

3D projections
Interactive holograms will allow students to walk around models of planets, animals and more, studying them in more detail.

Augmented learning
Glasses with special over-eye displays will let students view related, useful information around a subject as they learn.

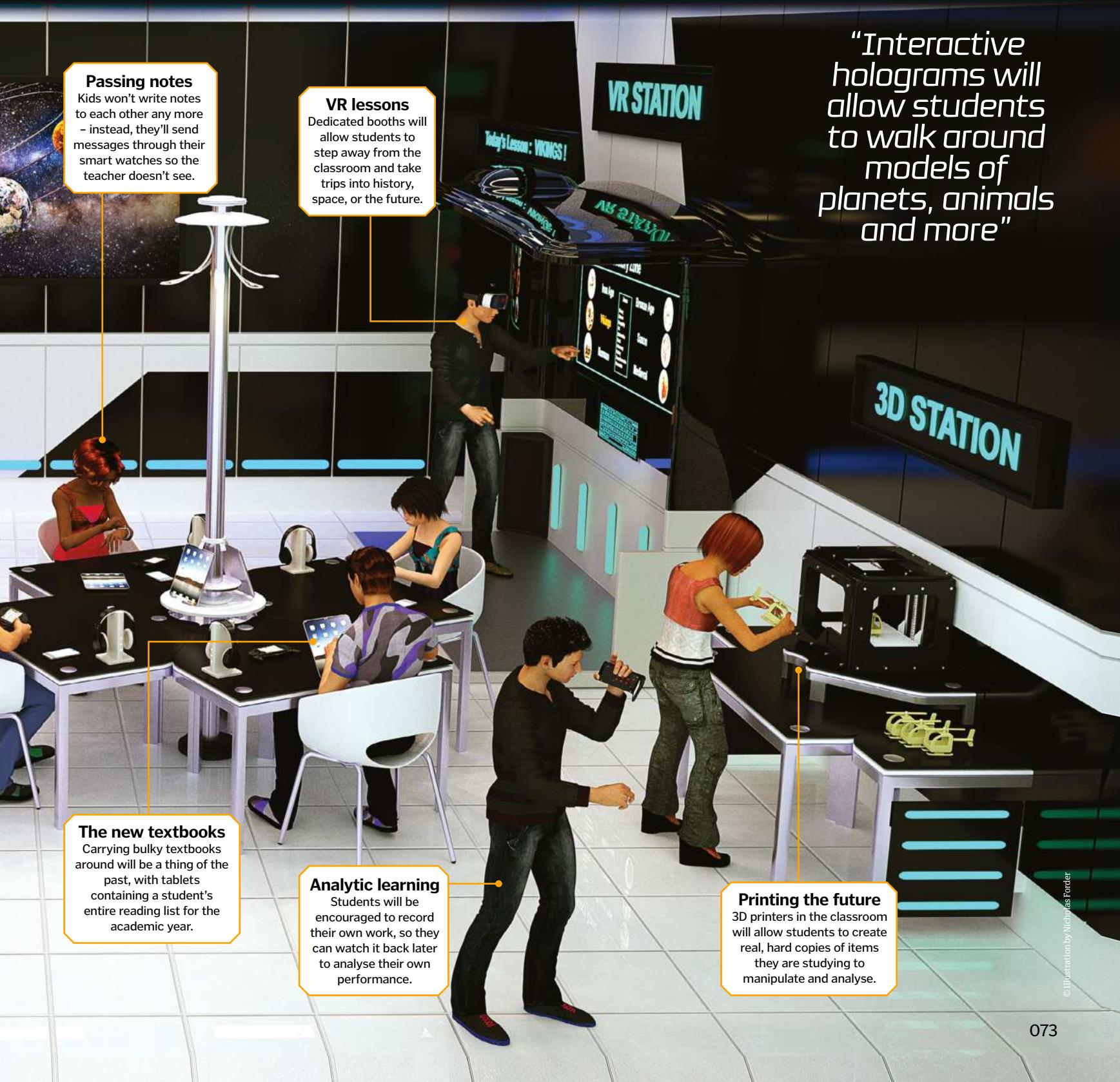
Gaming
Games will be introduced into the classroom as a tool for learning, making the classroom a more interesting and engaging place for students.

DID YOU KNOW? Currently, 3D printers can take hours to print small models, but in future models will be created in minutes



Passing notes

VR lessons



"Interactive holograms will allow students to walk around models of planets, animals and more"



Jetpack anatomy

See the clever design that keeps the gadget airborne and safe

Built-in safety

The parachute system automatically deploys if the engine fails, allowing the aircraft to slowly return to the ground.

In-flight controls

Two joysticks and a touchscreen control the aircraft; if the pilot releases these it will automatically hover at its current altitude.

Taking off

The aircraft takes off and lands vertically, much like a helicopter.

Pilot protection

The roll bar and arm restraints help to keep the pilot safe; the aircraft's structure adds additional protection from the rear and sides.

Carbon structure

The jetpack's central beam is made from carbon fibre with a foam core, while the fuel tank is encased in Kevlar and a fuel-resistant resin.

Fan propulsion

Two carbon fibre fan ducts provide thrust, drawing air in through the top, where it's accelerated by the rotors and then forced out of the bottom.

Powerful engine

The 200 horsepower, petrol-powered engine provides a top speed of 74 kilometres per hour.

Weighing 60 kilograms, the V4 engine produces 200 horsepower at 6,000 RPM



THE MARTIN JETPACK

How does this high-flying gadget take to the skies?

Ever since they first made an appearance in science fiction films, real jetpacks have been promised by a number of different companies and inventors around the world. With its latest prototype, the Martin Aircraft Company believes it has mastered this long anticipated personal aircraft.

Despite the name, it isn't actually powered by a jet engine. Instead, this contraption relies on a 200 horsepower, V4 engine, fuelled by a mix of regular petrol and two stroke oil – much like old

mopeds. This powers two carbon fibre fan ducts, one fitted to either side of the jetpack. Air is drawn in from above and accelerated using the fan's rotors, creating enough downforce to propel a payload of up to 120 kilograms to a height of around 900 metres.

The aircraft is made from sturdy, foam-filled carbon fibre, and can be piloted using two joysticks and a touchscreen, or flown from the ground via a remote control. It benefits from a fly-by-wire, semi-automatic system that helps to

balance out the controls between the pilot and the onboard computer. Once airborne, the Martin Jetpack can fly for roughly 30 minutes, achieving a top speed of 74 kilometres per hour.

When this jetpack does eventually go on sale, it will retail in the region of £99,000 (\$150,000). However, this won't just be reserved for gadget-loving millionaires. A number of emergency services are interested in using the jetpack; the Abu Dhabi fire service has already made a bulk order.



The ReFlex is the world's first wireless flexible smartphone

Your new flexible smartphone

Bend-control helps bring Angry Birds to life

Do you ever wish you could just take your bulky, rigid smartphone and roll it up to put it in your chest pocket? While it might sounds like science fiction, flexible and bendable smartphones are closer than you think – in fact, the technology already exists. When using the world's first wireless flexible

smartphone, you can interact with apps simply by bending the handset, as seen in the screen that LG showcased at the Consumer Electronics Show in 2016. So how does it work? Bend sensors behind the LG Display Flexible OLED touch screen sense the force you apply, and this information can be used to flick through the

pages of an e-book, or stretch the sling when playing *Angry Birds*. A voice coil inside the phone will then simulate the feedback from these actions through vibrations, helping you feel the rubber band stretch and snap back or the pages flip through your fingers. Your next LG smartphone could well be flexible!

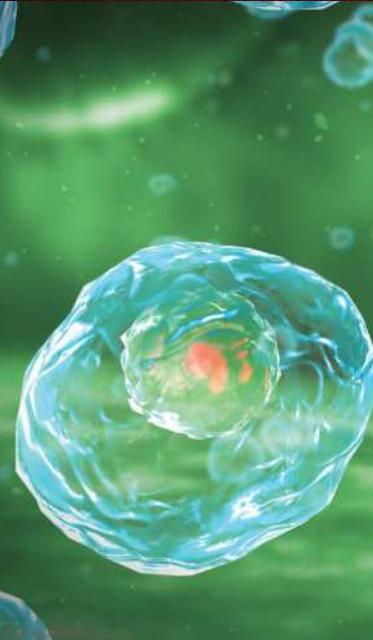


MEDICINE



096

Building a nanobot



088

Can malaria be cured?

78

Hacking the human body

How can technology complement our biology?

84

The future of medicine

Can we predict how fatal diseases might be cured?

90

Saving lives with nanotech

How these microscopic robots could be your new doctors

98

The antibiotic apocalypse

Can we fight the rise of the antibiotic-resistant superbug?

100

How we'll cure cancer

How understanding cancer will help us to treat it



090

Inside nanotech

HACKING THE HUMAN BODY

**YOUR BODY IS YOUR MOST VERSATILE TOOL,
BUT WHAT IF YOU COULD IMPROVE IT?**

We are limited by our biology: prone to illness, doomed to wear out over time, and restricted to the senses and abilities that nature has crafted for us over millions of years of evolution. But not any more.

Biological techniques are getting cheaper and more powerful, electronics are getting smaller, and our understanding of the human body is growing. Pacemakers already keep our hearts beating, hormonal implants control our fertility, and smart glasses augment our vision. We are teetering on the edge of the era of humanity 2.0, and some enterprising individuals have already made the leap to the other side.

While much of the technology developed so far has had a medical application, people are now choosing to augment their healthy bodies to extend and enhance their natural abilities.

Kevin Warwick, a professor of cybernetics at Coventry University, claims to be the "world's first cyborg". In 1998, he had a silicon chip

implanted into his arm, which allowed him to open doors, turn on lights and activate computers without even touching them. In 2002, the system was upgraded to communicate with his nervous system; 100 electrodes were linked up to his median nerve.

Through this new implant, he could control a wheelchair, move a bionic arm and, with the help of a matched implant fitted into his wife, he was even able to receive nerve impulses from another human being.

Professor Warwick's augmentations were the product of a biomedical research project, but waiting for these kinds of modifications to hit the mainstream is proving too much for some enterprising individuals, and hobbyists are starting to experiment for themselves.

Amal Graafstra is based in the US, and is a double implanter. He has a Radio Frequency Identification (RFID) chip embedded in each hand: the left opens his front door and starts his motorbike, and the right stores data uploaded

from his mobile phone. Others have had magnets fitted inside their fingers, allowing them to sense magnetic fields, and some are experimenting with aesthetic implants, putting silicon shapes and lights beneath their skin. Meanwhile, researchers are busy developing the next generation of high-tech equipment to upgrade the body still further.

This article comes with a health warning: we don't want you to try this at home. But it's an exciting glimpse into some of the emerging technology that could be used to augment our bodies in the future. Let's dive in to the sometimes shady world of biohacking.

"We are teetering on the edge of the era of humanity 2.0"

IMPLANTS

Professional and amateur biohackers are exploring different ways of augmenting our skin

Electronic tattoos

Not so much an implant as a stick-on mod, this high-tech tattoo from the Massachusetts Institute of Technology (MIT) can store information, change colour, and even control your phone.

Created by the MIT Media Lab and Microsoft Research, DuoSkin is a step forward from the micro-devices that fit in clothes, watches and other wearables. These tattoos use gold leaf to conduct electricity against the skin, performing three main functions: input, output and communication. Some of the tattoos work like buttons or touch pads. Others change colour using resistors and temperature-sensitive chemicals, and some contain coils that can be used for wireless communication.



Fingertip magnets

Tiny neodymium magnets can be coated in silicon and implanted into the fingertips. They respond to magnetic fields produced by electrical wires, whirring fans and other tech. This gives the wearer a 'sixth sense', allowing them to pick up on the shape and strength of invisible fields in the air.



The implants allow the wearer to pick up small magnetic objects

Under-skin lights

Some implants are inserted under the skin to augment the appearance of the body. The procedure involves cutting and stitching, and is often performed by tattoo artists or body piercers. The latest version, created by a group in Pittsburgh, even contains LED lights. This isn't for the faint of heart – anaesthetics require a license, so fitting these is usually done without.

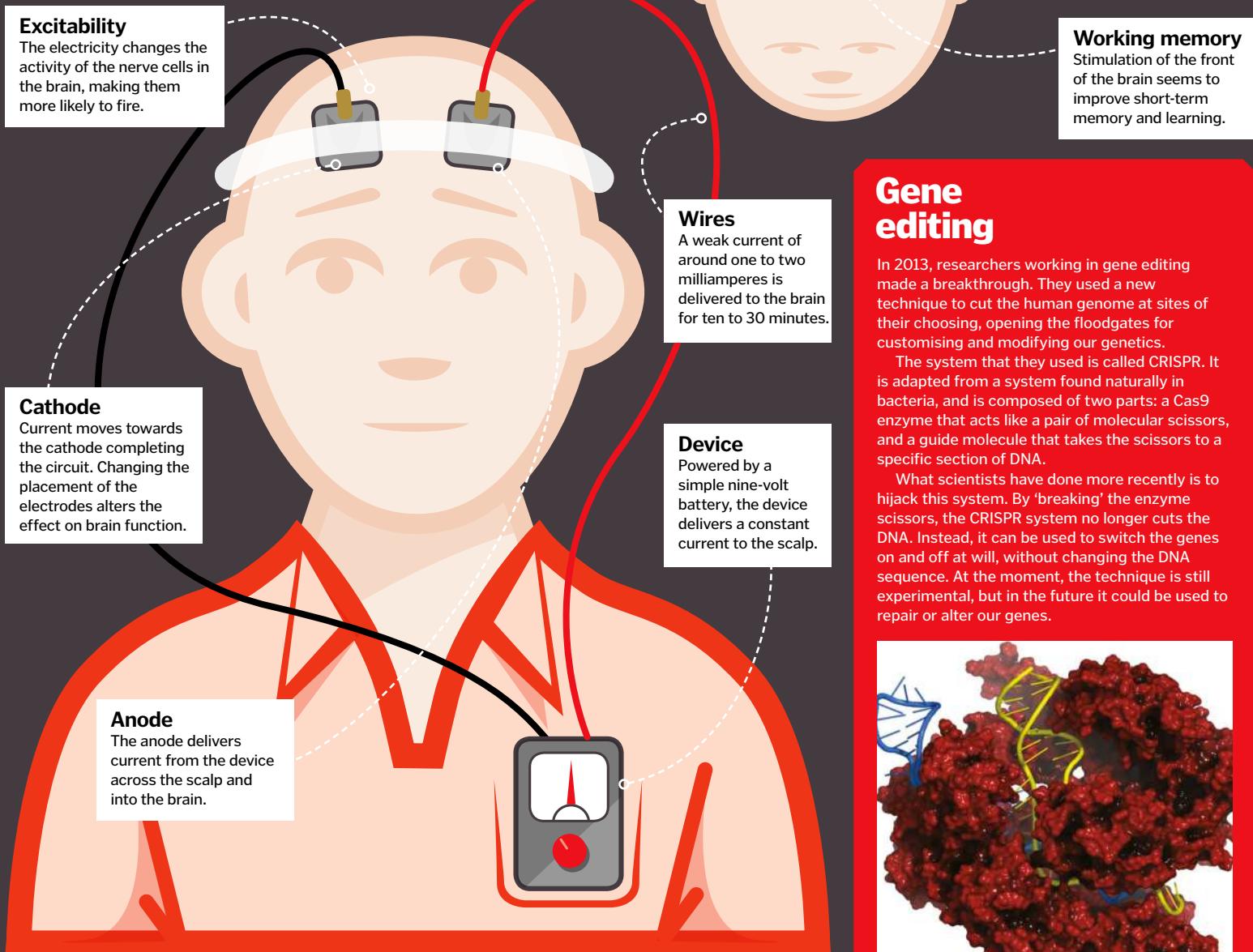


Grindhouse Wetware makes implantable lights that glow from under the skin



Buzzing the brain

Transcranial DC stimulation sends electrical signals through the skull to enhance performance



HACKING THE BRAIN

With the latest technology we can decipher what the brain is thinking, and we can talk back

The human brain is the most complex structure in the known universe, but ultimately it communicates using electrical signals, and the latest tech can tap into these coded messages.

Prosthetic limbs can now be controlled by the mind; some use implants attached to the surface of the brain, while others use caps to detect electrical activity passing across the scalp.

Decoding signals requires a lot of training, and it's not perfect, but year after year it is improving.

It is also possible to communicate in the other direction, sending electrical signals into the brain. Retinal implants pick up light, code it into

electrical pulses and deliver them to the optic nerve, and cochlear implants do the same with sound in the ears via the cochlear nerve. And, by attaching electrodes to the scalp, whole areas of the brain can be tweaked from outside.

Transcranial direct current stimulation uses the weak currents that pass through the skin and

"Prosthetic limbs can now be controlled by the mind"

bone to the underlying brain cells. Though this is still in development, early tests have indicated that this can have positive effects on your mood, memory and other brain functions. The technology is relatively simple, and there are some companies that are already offering the kit to people at home. It's even possible for you to make one yourself.

However, the researchers of this technology are urging caution. They admit that they still aren't exactly sure how it works, and messing around with your brain could have very dangerous consequences.

Exoskeletons and virtual reality

At the 2014 World Cup in Brazil, Miguel Nicolelis from Duke University teamed up with 29-year-old Juliano Pinto to showcase exciting new technology. Pinto is paralysed from the chest down, but with the help of Nicolelis' mind-controlled exoskeleton and a cap to pick up his brainwaves, he was able to stand and kick the official ball.

The next step in Nicolelis' research has been focused on retraining the brain to move the legs – and this time he's using VR. After months of controlling the walking of a virtual avatar with their minds, eight people with spinal-cord injuries have actually regained some movement and feeling in their own limbs.

Electrodes can pick up neural impulses, so paralysed patients are able to control virtual characters with their brain activity



Exosuits can amplify your natural movement, while some models can even be controlled by your mind

COMMUNITY BIOLOGY LABS

We spoke to Tom Hodder, technical director at London Biological Laboratories Ltd to learn more about public labs and the biohacking movement

Interview bio:

Tom Hodder studied medicinal chemistry and is a biohacker working on open hardware at London Biohackspace.

What is the London Biohackspace?

The London Biohackspace is a biolab at the London Hackspace on Hackney Road. The lab is run by its members, who pay a small monthly fee. In return they can use the facilities for their own experiments and can take advantage of the shared equipment and resources. In general the experiments are some type of microbiology, molecular or synthetic biology, as well as building and repairing biotech hardware.

Who can get involved? Is the lab open to anyone?

Anyone can join up. Use of the lab is subject to a safety induction. There is a weekly meet-up on Wednesdays at 7.30pm, which is open to the public.

Why do you think there is such an interest in biohacking?

Generally, I think that many important problems, such as food, human health, sustainable resources (e.g. biofuels) can be potentially mitigated by greater understanding of the underlying

processes at the molecular biological level. I think that the biohacking community is orientated towards the sharing of these skills and knowledge in an accessible way. Academic research is published, but research papers are not the easiest reading, and the details of commercial research are generally not shared unless it's patented. More recently, much of the technology required to perform these experiments is becoming cheaper and more accessible, so it is becoming practical for biohacking groups to do more interesting experiments.

Where do you see biohacking going in the future?

I think in the short term, the biohacking groups are not yet at an equivalent level to technology and resources to the universities and commercial research institutions. However in the next five years, I expect more open biolabs and biomakerspaces to be set up and the level of sophistication to increase. I think that biohacking groups will continue to perform the service of communicating the potential of synthetic and molecular biology to the general public, and hopefully do that in an interesting way.

Community labs are popping up all over the world, providing amateur scientists with access to biotech equipment





BUILDING FUTURE YOU

A closer look at some of the emerging tech that will allow you to customise your body

Self-improvement is part of human nature, and technology is bringing unprecedented possibilities into reach. Much of the development up until this point has had a medical purpose in mind, including prosthetic limbs for amputees, exoskeletons for paralysis, organs for transplant, and light sensors for the blind. However, with the advent of wearable technology, and a growing

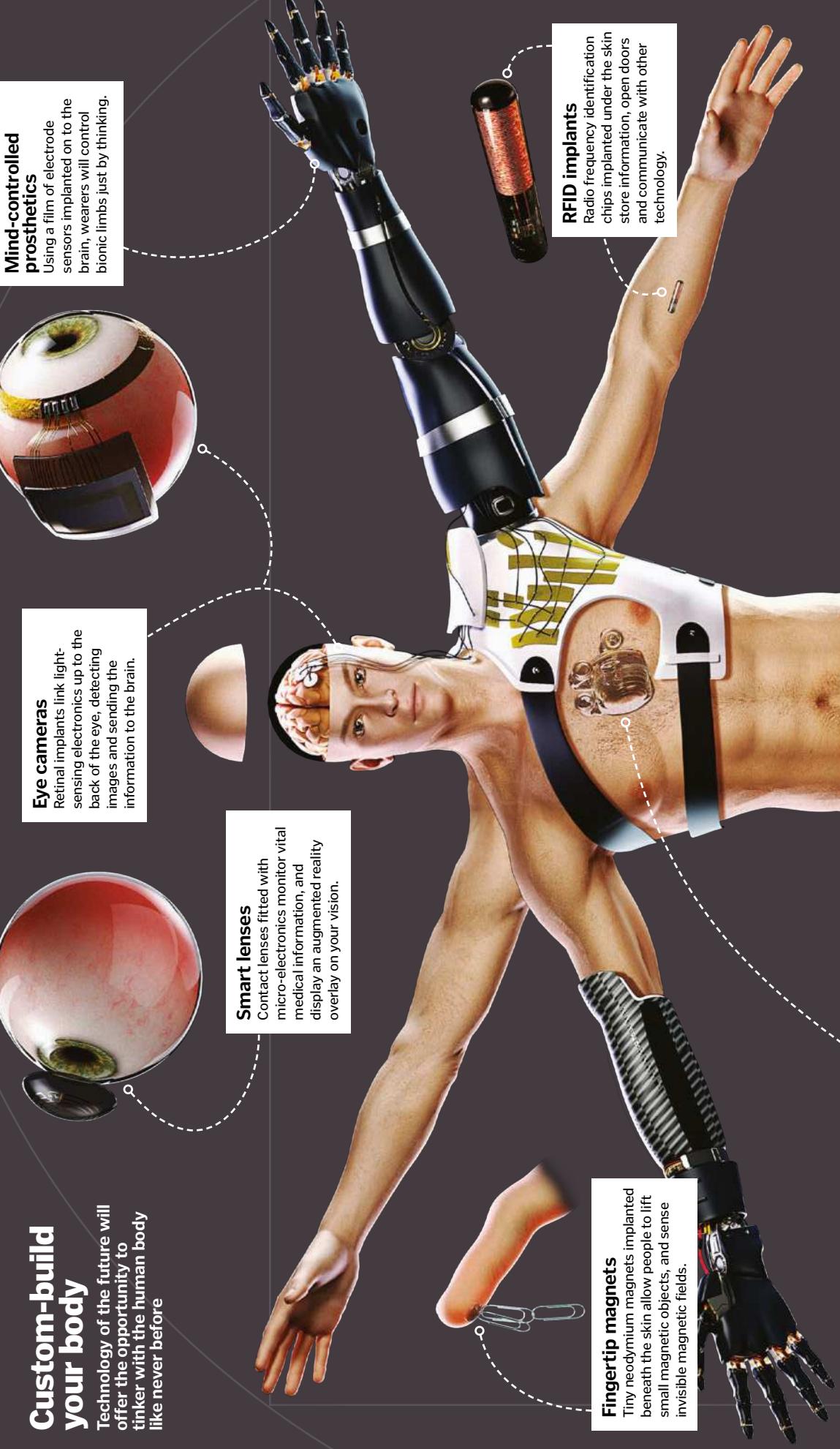
community of amateur and professional biotechnology tinkerers, there is increased interest in augmenting the healthy human body.

The first cyborgs already walk among us, fitted with magnetic sensors, implanted with microchips, and talking to technology using their nervous systems. At the moment, many devices are experimental, sometimes even homemade

Custom-build your body

Technology of the future will offer the opportunity to tinker with the human body like never before

and unlicensed. However, the field is opening up, and the possibilities are endless. So, what does the future hold for a customisable you? Medical implants could monitor, strengthen, heal or replace our organs. We could add extra senses, or improve the ones we already have. And, one day we might be able to tap straight into the internet with our minds.



Bionic organs
Replacement organs will be grown from real human cells in the lab, or reconstructed using synthetic materials and electronics.

Exoskeleton support
Robotic exoskeletons support the wearer's limbs, using hydraulics in place of muscles, and hinges in place of joints.

Smart bandages
Wound dressings will be equipped with sensors to monitor healing and flag up the first signs of infection by turning fluorescent green.

Interchangeable limbs
Advanced prosthetics could give amputees superhuman abilities, and the option to switch between designs to suit the situation.

Electronic tattoos
Gold-leaf temporary tattoos can be used as touch sensors, colour-changing indicators, and for Wi-Fi communications.

"Many devices are experimental, sometimes even homemade"

© Shutterstock; Google; Touch Bioart; Illustration by Nicholas Foster; Ekso Bionics

The Argus implant's camera and transmitter signal to the optic nerve

This RFID chip shows the coiled copper antenna it uses to communicate

Google is developing a contact lens that senses blood sugar by analysing tears

Ekso moves legs in response to upper body movement



THE FUTURE OF MEDICINE

How are we going to beat the world's deadliest diseases?

Medical science has produced some incredible solutions to challenging problems over the decades, from antibiotics to fight bacterial infection, to imaging technologies to look inside patients without using a knife. It's hard to predict what will happen next, but science has recently opened some really exciting doors to the future of medical treatment.

Medicine is no longer just about biology and drugs. Computing, engineering, nanotechnology, quantum physics, and many more disciplines are leaking over into medical

tech and providing brand new solutions to age-old problems.

In the hospitals of the future, augmented reality could allow surgeons to see through their patients, and contact lenses could monitor blood sugar for diabetics. Prosthetic limbs linked directly to the nervous system could allow amputees to move and feel just by thinking, and 3D printers could be utilised to create custom medical kit, or even fully working replacement organs, on demand.

We are learning how to retrain our own immune systems to fend off deadly diseases, and

we are developing technology that could allow our own genetics to be tweaked and changed on the go. The scientific community has access to a massive and rapidly expanding pool of data from patients the world over, and as we dig deeper into the biochemistry of illness, new ways to precisely treat disease are set to appear.

One day, wearable tech and at-home test kits could monitor for the first signs of sickness, and custom treatments might be delivered based on our own unique genetic and biochemical fingerprints, minimising side effects and maximising our chances of recovery.

How germs spread



Body fluids

Blood, saliva, semen and breast milk can all carry disease

Liquids provide an excellent way for pathogens to travel from one place to another. Precautions are always taken when dealing with body fluids in hospitals and labs, because contaminated body fluids can transmit diseases like mumps, hepatitis and HIV.



Food and drink

Contaminated food and drink carry pathogens into the gut

The acidity of the stomach provides some protection against infection, but it can't stop everything. Pathogens enter through the mouth, and either set up home in the digestive tract, or move into the body through its walls.

Skin to skin contact

Some infections are quickly spread by direct contact

Chickenpox, cold sores, head lice and warts can all be transmitted by touching someone with the infection; the viruses, bacteria, or parasites simply move from one person to another. Some of these examples can also survive on inanimate surfaces for a short time.



Droplets

Pathogens can be transmitted short distances by drops of liquid in the air

Tiny drops of fluid released by a cough or a sneeze travel around a metre before they settle onto door handles, surfaces and skin. It's an easy way for respiratory infections to spread. Examples include colds, flu and rubella.

Preventing history's biggest killers

Vaccinations teach the immune system how to fight, before it encounters the disease

Our natural defence against disease is our immune system. It's an army of cells that work together to patrol the body and destroy anything that shouldn't be there. It's split into two parts, a fast-response 'innate' system, that wages war at the first sign of trouble, and a slow, specialised 'adaptive' system that delivers a stronger and more focused attack.

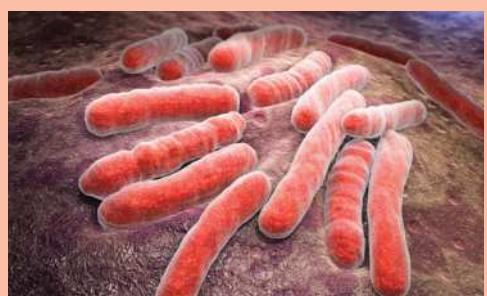
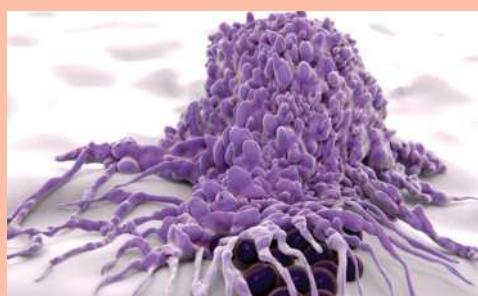
The first time the immune system meets a new infection, it takes up to a week for the specialised immune cells to appear. In this time, the pathogen can multiply, and people can become very sick. Vaccinations bypass this step by giving the immune system a chance to train beforehand.

The first vaccine was developed by Edward Jenner in 1796. He noticed that milkmaids didn't catch smallpox; they were exposed to a similar disease, cowpox, and their immune systems were better trained. Jenner tried infecting children with cowpox, and found that they too gained protection.

Vaccinations have been developed against dozens of infectious diseases, and they are now being made to teach the immune system to fight other illnesses too.



Training the immune system



Vaccinations are like a training program for your immune system, giving it a sneak peek at enemies that it might encounter in the future so that it can prepare in advance. They can be made in different ways, but usually contain inactive bacteria or viruses, or examples of molecules that the pathogens make.

When the vaccination has been injected, your immune system comes to have a look. It will examine the parts of the pathogen and work out the best way to attack, as though it were fighting the real thing. After the vaccine has been cleared up, some of the cells that fought it remain in the body on patrol as 'memory cells'.

When you encounter the real pathogen, your immune system will be ready to respond. Instead of spending time working out what to do, the memory cells left over from the vaccine instantly clone themselves, producing an army of cells that can clear the infection before you get sick.



37 million

In 2015, nearly 37 million people were living with HIV

Over half of people with HIV can't access treatment

1.1 million

people die as a result of AIDS each year



HIV is transmitted through body fluids, including blood, semen and breast milk



40%

of people with HIV don't know they're infected



Antiretroviral therapy stops the virus replicating

Condoms, HIV testing, and circumcision help to reduce transmission

HIV puts people at risk of catching other diseases like tuberculosis

The end of HIV

How do you hunt down a virus that's hiding in your own immune system?

Human Immunodeficiency Virus (HIV) hijacks the immune system. The virus gets inside, inserts its genetic code into the genome of a cell, and transforms it into a factory to make more of the virus. While this is happening, the cell is unable to function normally, and gradually as more and more cells are taken over, the immune system is left seriously weakened. The result is known as Acquired Immune Deficiency Syndrome (AIDS).

HIV is now treatable with a combination therapy that stops the virus from replicating. The amount of virus often dips so low in the blood that the disease can't be passed on. Transmission from mother to child is also being eliminated with new drugs. However, not everyone has access to treatment.

The gold standard for the future of HIV medicine would be a vaccine that can teach the immune system to neutralise the virus with a coating of antibodies. In theory, this could be used not only to prevent infection, but also to stop the disease coming back in people who have some virus still hiding in their systems.

This is a huge challenge; the virus shape-shifts to avoid detection, and the immune system doesn't usually respond. But new vaccines are being trialled all the time, and as our understanding of HIV and the immune system improves, we are inching closer to making it a reality.

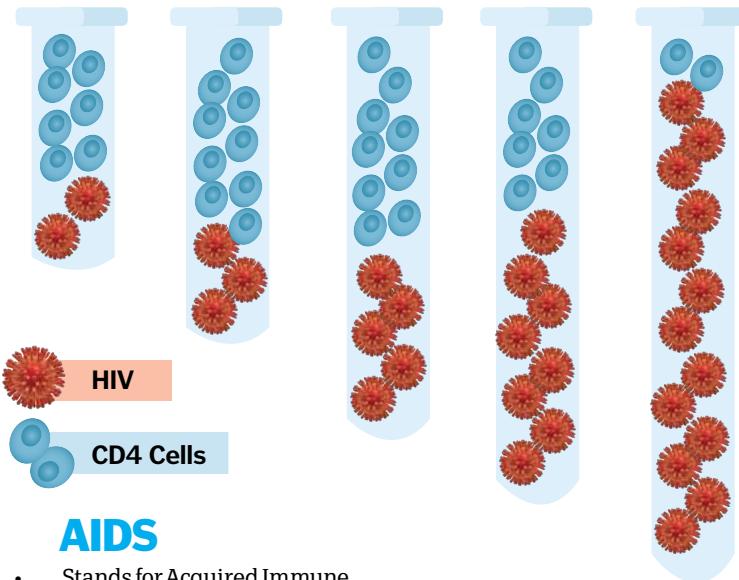
How hard is it to cure?

HIV stiches its genome into to the genome of immune cells, so that the two are permanently linked together. Antiretroviral treatment can stop the virus from making copies of itself, but they can't get rid of it completely unless the immune cells themselves are killed.

This has been done once, in 2007. The Berlin Patient had cancer and needed a bone marrow transplant. His own immune

system, carrying the HIV, was destroyed, and replaced with donor cells. They had a genetic mutation that made it harder for HIV to infect them, and the patient was cured.

Bone marrow transplants are risky, however, and there aren't enough donors available, so it's not a practical solution to rid the world of HIV altogether.



AIDS

- Stands for Acquired Immune deficiency Syndrome
- Is the disease caused by HIV
- Takes advantage of the damaged immune system that is unable to fight it
- People die due to infection or resulting cancer

HIV

- Stands for Human Immunodeficiency Virus
- Is the virus that causes AIDS
- It infects the immune system
- Infection compromises the cells of the immune system

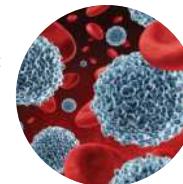
Timeline

1981

Men in California start to fall ill with unusual infections after their immune systems become weakened.

1983

Scientists discover that human immunodeficiency virus (HIV) is the cause of acquired immune deficiency syndrome (AIDS).



1985

Commercial blood tests for HIV are invented, allowing screening to begin.

1987

The first drug treatment for HIV, azidothymidine, is approved.



1996

Triple-drug therapy is introduced, turning HIV infection into a long-term disease.

2007

A single patient in Berlin is cured by a pioneering bone marrow transplant.

Future

A vaccine is developed to train the immune system to attack HIV.

Future

A drug is developed to reveal HIV lurking in dormant cells.

Can cancer be cured?

Huge progress has been made over the past century, but what happens next?

Cancer is an ancient disease; tumours have been found in Egyptian mummies, and even in the fossils of dinosaurs. It happens when genes involved in growth and repair go wrong. Affected cells make copy upon copy of themselves, and these new cells start to break away, travelling around the body and making yet more copies elsewhere.

If cancer is caught early, it can already be cured. If the tumour is removed, the cancer is gone. However, once the cancer has spread it is harder to treat, and the more it spreads, the less likely people are to survive.

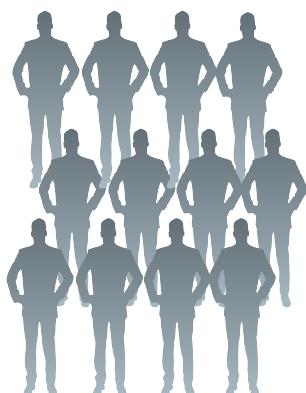
Stopping cancer before it really starts would be the best option. Vaccinations might be used to train the

immune system to recognise cancer cells, or a routine blood or breath test could be developed to pick up the earliest signs of the disease. However, the likelihood of cancer increases with age, and with people living longer the incidence is rising.

For those who do develop the disease, several futuristic treatment options are already being developed. Future humans could end up having their immune systems retrained and augmented, or they might receive genetically engineered viruses designed specifically to infect and kill the tumour. We might even be able to switch genes on and off inside tumour cells to halt their growth.

The future of cancer medicine

Matching people to the right treatment could be the answer to controlling cancer



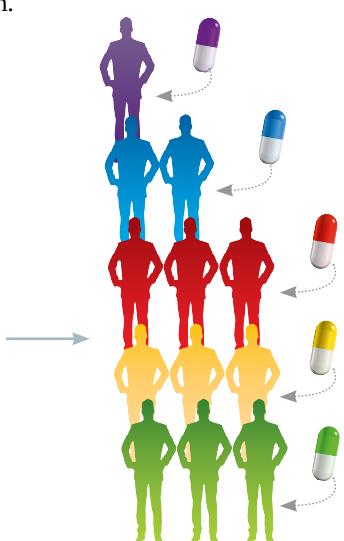
Group of patients

Several people might have brain cancer, but not all brain cancers are the same.



Genetic testing

The patients are tested to find out the exact genetic and chemical makeup of their tumour.



Treatment matching

Patients are matched with treatments that specifically target the weaknesses of their own cancer.

Where is the cancer cure?

Cancer gets a lot of research money, and thousands upon thousands of scientists are working to try and find the cure, so where is it? If you can cut the tumour out before it has a chance to spread, you can cure it, but if any cells have escaped they need to be found. Radiotherapy and chemotherapy can help to mop up stragglers, but they don't always work, and

some cancer cells develop ways to avoid them. The big challenge is that everyone is different, and so too are everyone's cancers. And tumours don't just differ between people, they also change over time. The challenge is to find out how they change, and how these different weaknesses can be targeted with treatments.

1880s
The first mastectomy is performed, finally providing treatment for breast cancer.



1950s
Smoking is finally shown to cause lung cancer, encouraging millions to give up.

Future
Personalised medicine becomes reality, with patients matched to treatments based on their genes.

Timeline

1846
The invention of general anaesthetic paves the way for surgery to finally remove tumours.



1903
Radium is used to treat skin cancer, the in what is the first example of radiotherapy.

1949
The first chemotherapy drug is approved. It is nitrogen mustard, a WWII weapon.

1990s
Cancer mortality starts to drop in developed countries as diagnoses and treatment improve.

Future
A simple blood test is developed to pick up the very earliest signs of cancer.

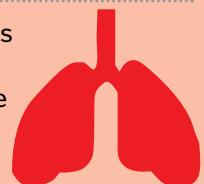
14 million

people are diagnosed with cancer each year

8 million

people die of cancer each year

Lung cancer is the most common type of cancer in men



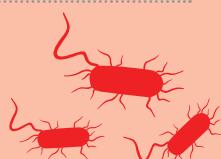
Breast cancer is the most common type of cancer in women

The older you are, the more likely you are to get cancer



Cancer is not contagious, but it can be genetic

Viral infections can cause some cancers



The earlier cancer is detected, the easier it is to treat



Lifestyle changes could prevent a third of cancers





10-18

days it takes for malaria parasites to reproduce inside a mosquito



Malaria was first written about in Ancient China in 2700 BCE

3.2

billion people live in regions where they could catch malaria

400,000

people die of malaria each year

70%

of malaria deaths are children under the age of five

Malaria is caused by parasites that infect humans and mosquitoes



Spraying houses with insecticide is the best way to stop transmission

Last year
95 countries reported cases of malaria

214 Million cases of malaria in 2015

Eliminating malaria

This deadly disease is carried by mosquitoes, but work is being done around the world to wipe it out

Just one mosquito bite is enough to kill you in some parts of the world. Inside the midgut of Anopheles mosquitoes, gametocytes from the plasmodium parasite mature and combine. These are the equivalent of human sperm and eggs, and the result is hundreds of newly formed parasites ready to infect their next victim.

The parasites migrate up to the mosquito's salivary glands, and when it feeds again they enter the human bloodstream. They infect cells in the liver and begin to divide, before spreading back into the blood. As they continue to grow, the cells split open, releasing even more parasites and causing havoc for the body.

Malaria parasites can't reproduce without both mosquitoes and humans, giving us a tantalising opportunity to eliminate them. One idea is to genetically modify colonies of mosquitoes and release them to breed with their wild counterparts; this could be used to introduce damaging genetic traits into the population, either killing the parasites, or killing the mosquitoes themselves. Another option is to develop fungi that can infect and kill the insects.

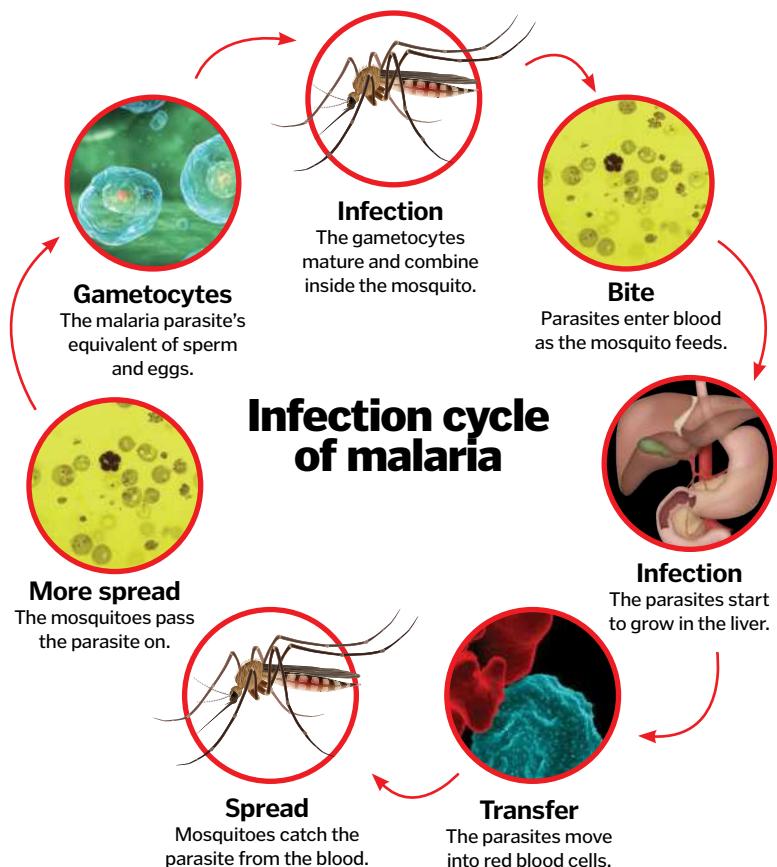
Other options for elimination include designing new insecticides to keep insect numbers down, and developing a vaccine to halt transmission.

Global elimination is tough

The World Health Organisation first initiated an attempt to rid the world of malaria in 1955. The idea was to use a combined attack, spraying houses to get rid of the mosquitoes, and using antimalarials to kill the parasites. They had some successes in areas where the climate was moderate and mosquitoes thrive only during certain seasons, but in other places the program didn't work as well.

Mosquitoes started to become resistant to pesticides, and the parasites resistant to treatments. This, combined with wars, political unrest, and patchy access to resources, meant that coordinating a global attack against malaria became almost impossible.

In 2015, the WHO reissued their challenge. But today we are facing even stronger versions of the parasite and vector, and new weapons are needed to eliminate them.



Timeline

1880

The parasite that causes malaria is discovered in blood samples taken from patients.

1939

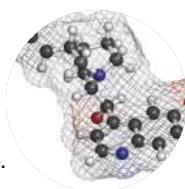
The DDT pesticide is invented, allowing people to control numbers of malaria-carrying mosquitoes.

Future

Malaria-carrying mosquitoes are wiped out by genetically modified insect mates.

1600s

Peruvian tree bark is used to treat malaria, eventually leading to the modern drug quinine.



1897

It's discovered that mosquitoes are able to transmit malaria from one person to another.

1951

Malaria is wiped out in the US after a government eradication program sprays millions of homes.

2015

The World Health Organisation endorses a new strategy to eliminate malaria for good.

Future

The world is declared malaria free thanks to the eradication campaign.

Halting heart attacks and strokes

Diseases of the heart and blood vessels are the world's biggest killers

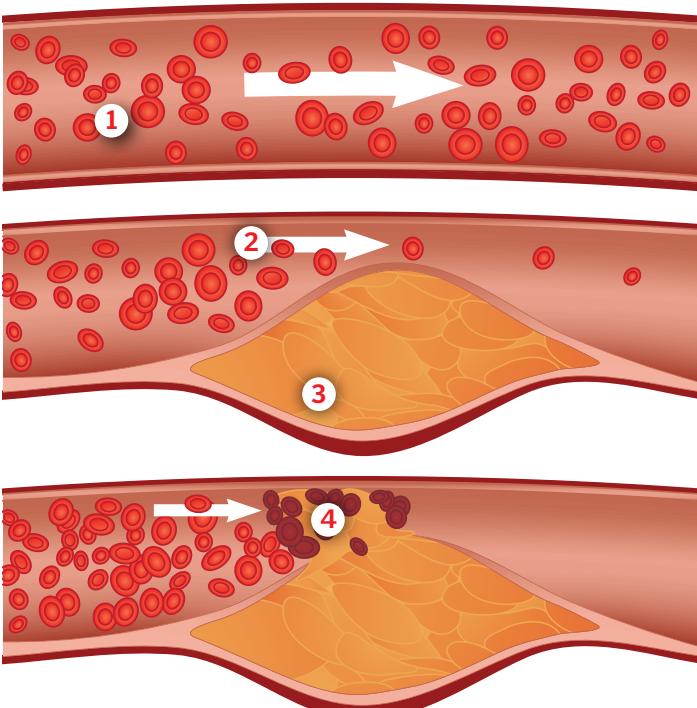
When arteries and veins become clogged with fat, rough plaques form and narrow the tubes. As the blood tries to force its way through it swirls and twists, and more damage is done. The fatal blow comes when parts of the blockage break away. Clotting molecules in the blood interpret the roughness as a cut that needs to be sealed. They start to build a clot, and as the circulating blob gets larger, it eventually becomes lodged in the tubes, cutting off the blood supply.

The damage can't always be repaired, but the latest research could change that for the future. Stem cells are cells that haven't yet decided which part of the body to become. With some coaxing in the lab, they can be converted into new blood cells, new skin cells, or even new heart muscle. Harvard scientists have already made a life-size beating heart by convincing stem cells to become heart muscle and growing them on a scaffold. In the future, custom organ replacements could be made artificially on demand.

If this doesn't work, another option is gene therapy, which is already being trialled for heart failure. Genes are delivered to the cells, telling them to make different molecules, and potentially allowing the body to be reprogrammed from the inside out.

How heart disease starts

The slow accumulation of fat can lead to a deadly blood clot



1 Normal vessel

Healthy blood vessels have smooth internal walls, allowing the blood to slip easily around the body.

2 Disruption

When a blockage appears in the vessel, the blood quickly becomes backed up.

3 Plaque

Fatty deposits in the wall of the blood vessel cause it to bulge, narrowing the tube. A clot starts to form on the roughened surface, and the blood vessel becomes clogged.

4 Clotting

A clot starts to form on the roughened surface, and the blood vessel becomes clogged.

Why haven't we cured it?

Cardiovascular disease is difficult to treat once a catastrophic event has happened; strokes and heart attacks deprive vital organs of oxygen, and the affected tissue quickly dies. If you have a heart attack outside of a hospital, you have just a one in ten chance of surviving, and quarter of

people who suffer a stroke will die within a year.

In order to meaningfully improve treatment of cardiovascular disease, we need to be able to repair or replace damaged tissues, or we need to prevent it happening in the first place. Neither one is easy to do.

Timeline

1930
The defibrillator is invented, allowing stopped hearts to be restarted with electricity.



1967
The first human heart transplant is performed, allowing damaged organs to be replaced.

Future
Custom-grown replacement hearts are produced from people's own stem cells.

1899
Pharmaceutical company Bayer begin manufacturing a new drug called aspirin in Germany.



1958
The first implantable pacemaker is installed, allowing the heart to be controlled.

1960
The first heart bypass surgery was performed to divert blood around damaged vessels.

1987
The first cholesterol-lowering statin drug hits the market, helping to prevent heart attacks.

Future
Gene therapy is used to reverse the damage done by heart attacks.

Cardiovascular disease killed

17.2

million people in 2012



Heart attack symptoms include chest, arm and jaw pain, sweating and vomiting



Someone has a stroke every 2 seconds



There are over 2.5 million heart attack and stroke survivors in the UK



Men are more likely to die of heart disease than women



A third of adults in the UK have high cholesterol

The most important risk factors are smoking, diet, exercise and alcohol intake



Stroke symptoms include sudden weakness on one side of the body, confusion and slurred speech



Heart disease and stroke are the first and second most common causes of death



SAVING LIVES WITH NANOTECH



Meet the minuscule medics that could conquer incurable disease

What if we could control entire systems on the molecular level? What if inside your cells you had millions of helpers; tiny guardians tasked with clearing toxins from your body and keeping you in tip-top condition, removing pathogens before they have a chance to cause harm? This is one of the main goals of nanotechnology – an advanced field championed by scientists, engineers and mathematicians who are busy developing machines that would fit inside the eye of a needle.

It may seem truly exceptional and perhaps impossible, but all living organisms rely on machines such as these. Some species of bacteria, for example, propel themselves along using a spinning tail called a flagellum, which is powered by a rotating motor built from a ring of proteins. This operates in much the same way as the mechanical variants we use in industry, but just on a much smaller scale. Our own cells are also filled with dedicated machinery known as organelles that are responsible for certain jobs including the assembly, packaging and transport of materials inside and outside of the cell. The ribosome is one such example of a complex machine that fits nicely inside a cell, where it efficiently assembles proteins from genetic code. So our bodies are already packed with natural nanotech, but now the goal is to manufacture the artificial kind.

Synthetic structures are identified as pieces of nanotechnology when they range in size from one to 100 nanometres, so even at their largest they're 5,000 times smaller than this full stop. They're incredibly small pieces of tech! Nanotechnology has a wide range of potential applications, particularly in medicine, where nanomachines

What could nanomedicine do for us?

A dedicated task force of tiny structures could repair and improve our bodies

Connected

Nanobots swimming in the capillaries of our brains could allow our thoughts and emotions to be uploaded to cloud servers.

Glaucoma treatment

Contact lenses containing nanoparticles could periodically release beneficial drugs when placed onto the eye, helping to manage symptoms.

Improved oxygen supply

Mechanical red blood cells known as respirocytes could carry additional oxygen around the body to improve physical performance.

Antiviral

Viral infections could be kept at bay by nanoparticles that bind to viruses and stop them from spreading.

Biocapsules

Carbon nanotubes packed with insulin-producing cells could be inserted under the skin, and the contents would be released when blood sugar levels were high.

Youthful appearance

Wrinkles could be prevented by nanoparticles that penetrate deep into the skin, transporting compounds to make skin smoother and plumper.

Enhanced dental implants

Titanium dioxide nanotubes loaded with silver nanoparticles could surround implant material to improve adhesion to the bone and protect against infection.

Heart repair

Nanoparticles coated with sticky proteins could escort therapeutic drugs to damaged arteries, repairing the elastic walls.

Bone regeneration

Nanostructures could act as scaffolds to support bone repair after injury.

Cancer targeting

Cancer-fighting drugs could be guided to tumours by nanoparticles capable of recognising the cancerous cells.



could move freely through our vessels to support and repair our cells and tissues. While the idea of these mini-medics is theoretical for now, drugs involving nanoparticles are currently being used to treat certain diseases.

Nanomedicine could also join the fight against cancer. Already in labs across the world, scientists have started to develop pieces of nanotech capable of identifying cancer in its early stages, just by testing a small amount of blood or saliva. Once perfected, this could be a huge milestone in diagnosing a disease that is currently very difficult to notice before tumours have grown. Even if these reporters are not used in time then nanoparticles could come to save the day, having also been used as homing missiles to deliver chemotherapy drugs directly to cancer cells.

New methods of fighting disease are an exciting prospect, but nanotechnology promises even more. Currently incurable disorders like degenerated and severed neurons that lead to paralysis could be healed with nanostructures in the future, and researchers plan to use

nanomachines to patrol the cells and systems of our bodies to prevent diseases before they have the chance to cause damage. These envisioned nanobots could be remote-controlled externally or left to roam the body freely. We will even be able to equip them with minuscule arms for clearing unwanted molecules and power them with motors much like the ones found in bacteria.

And we needn't stop at keeping ourselves healthy, as nanotechnology could also be used to enhance our bodies beyond their natural capabilities. Our stamina and endurance could be massively improved by using nanoparticles to carry extra molecules of oxygen in the bloodstream to support the work of red blood cells. This could grant us the ability to hold our breath for several hours underwater – in theory, nanotechnology could be the tool that creates the very first superhumans.



Right now, nanotechnology is still in its early stages, but it is already being incorporated into everyday items, including sun creams, clothing and waterproof phone coatings.

Building things hundreds of times smaller than the text you're reading is very tricky, and particles don't always play by the same rules as we do. At the atomic level, the laws of physics as we experience them no longer wholly apply, and we enter the realm of quantum mechanics. Despite these obstacles, advances in technology allow us to peer into this invisible world, and to see and interact with structures at an atomic scale. As we learn more about the properties of certain atoms and molecules, we will be able to manipulate matter at the nanoscale to develop new and improved materials and structures. From engineering to medicine, the building blocks of tomorrow's tech are set to be very small indeed.

How small is small?

The nanoscale takes the definition of tiny to a whole new level

Hydrogen atom Size in nm: 0.1

The smallest atom is composed of just one proton and one orbiting electron.

Glucose Size in nm: 1

A single molecule of sugar is composed of only 24 atoms.

Copper atom Size in nm: 0.14

Copper atoms can be used to form copper nanoparticles, which are used for a variety of purposes in medicine and electronics.

Water molecule Size in nm: 0.28

Two atoms of hydrogen and one atom of oxygen come together to form this small molecule.

Gold atom Size in nm: 0.14

Atoms of gold can be assembled to form nanoparticles known as colloidal gold.

Single-walled carbon nanotubes Size in nm: 1

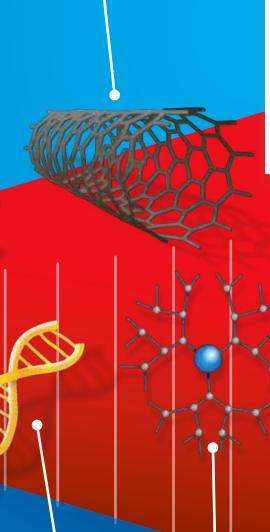
Sheets of graphene rolled into cylinders create tiny tubes close to 1nm wide.

White blood cells Size in nm: 5,000-20,000

Your body contains several different types of white blood cell, all of which are small enough to migrate out of blood vessels.

Human hair Size in nm: 80,000

A 'hair's breadth' is used to describe an incredibly small distance, but most hairs are at least 800 times wider than nanomachines.



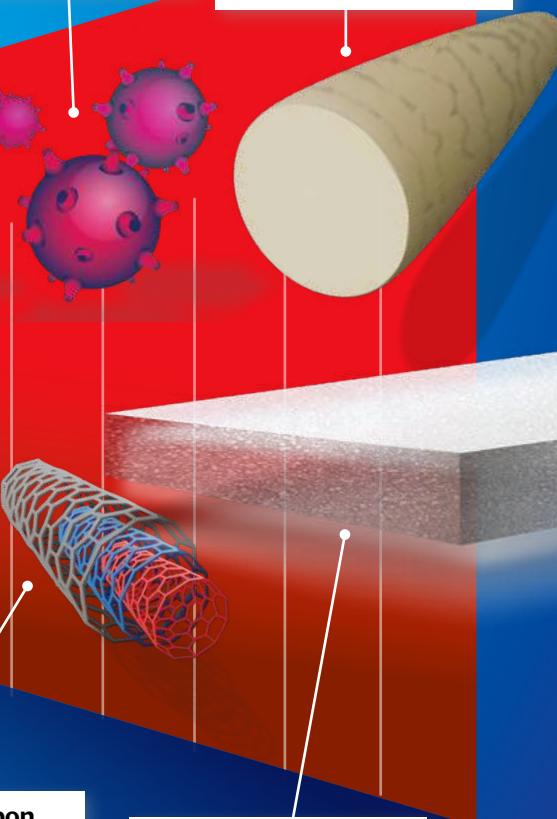
Dendrimers Size in nm: 5

These synthetic molecules are made of a central core surrounded by branch-like structures and coated with an outer shell. They can be used for drug delivery.



Multi-walled carbon nanotubes Size in nm: 2-50

These synthetic nanostructures are built using rings of carbon atoms that are arranged in multiple layers of tubes.



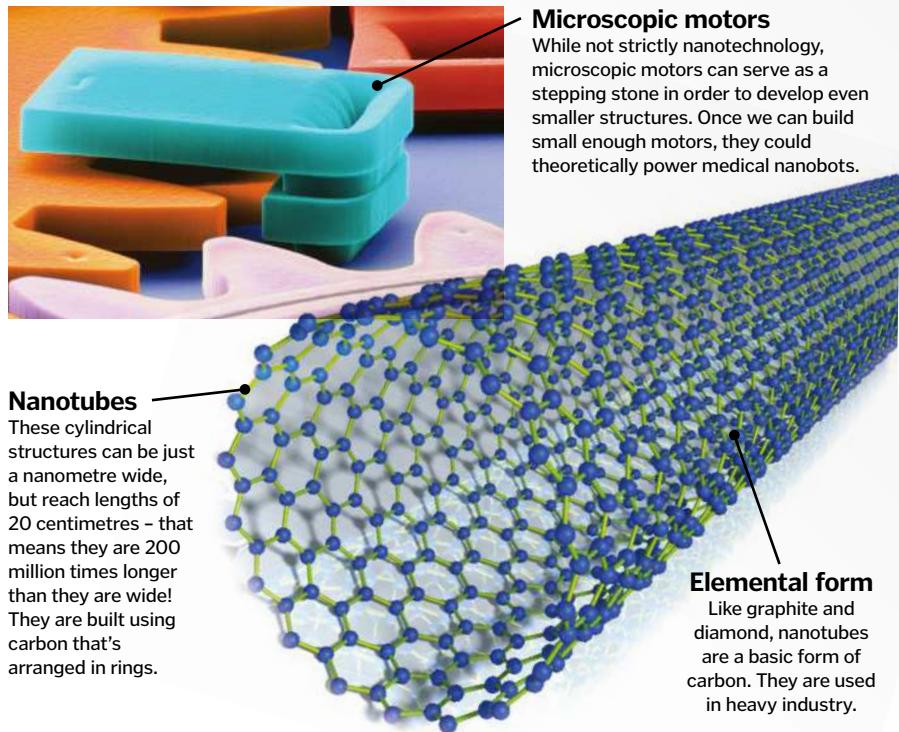
Sheet of paper Size in nm: 90,000

Although it may appear incredibly thin to us, over 450,000 atoms form the width of a sheet of paper.

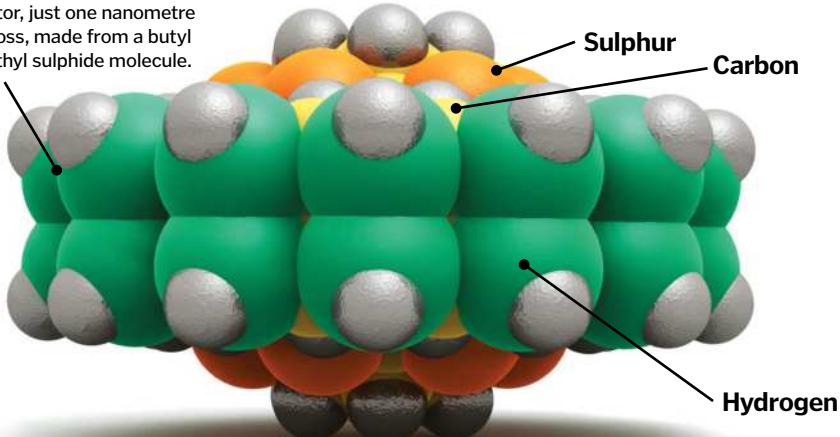
TYPES OF NANOTECHNOLOGY

What objects can we create by manipulating molecules and atoms?

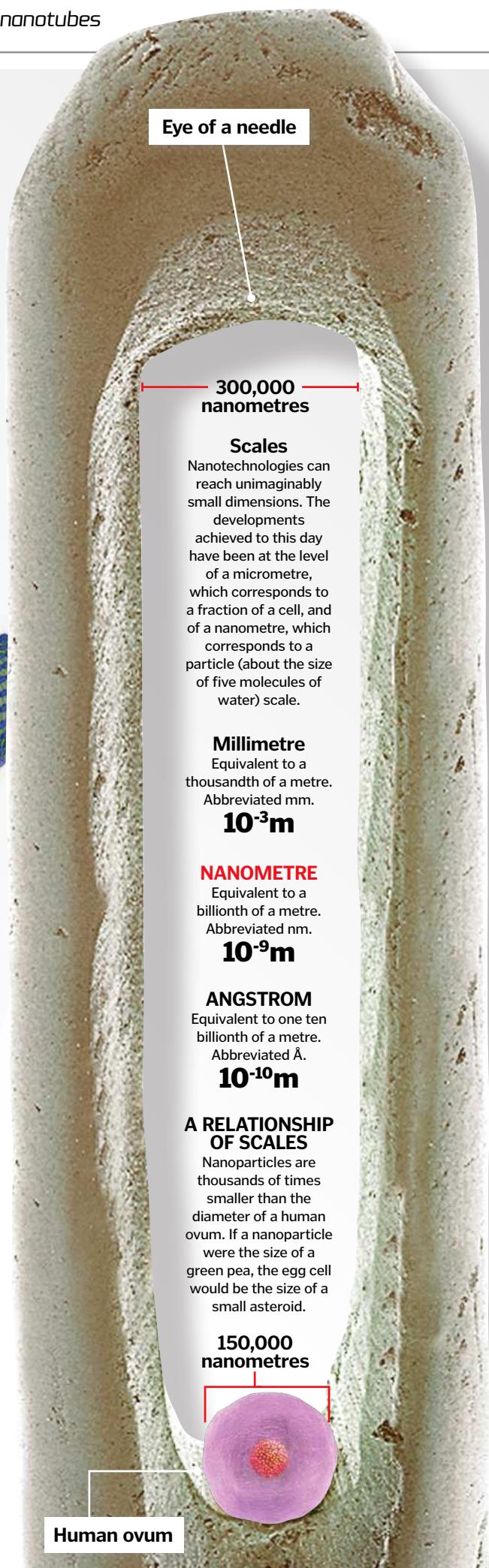
Much like natural nano-sized structures and molecules, synthetic pieces of nanotechnology are a diverse group. By using our knowledge of how atoms are arranged into structures, we can design and model different shapes with a wide range of properties. Nanotechnology can vary from relatively simple to immensely complex structures: some are used solely as protective housings with the responsibility of transporting drugs, and others have intricate mechanical actions such as mimicking a wheel spinning on an axle.



Engineered nanomolecules
Molecules can be modified and manipulated to build custom nanomachines. In 2011, a team of researchers created the smallest-ever electric motor, just one nanometre across, made from a butyl methyl sulphide molecule.



"Nanotechnology can vary from relatively simple to immensely complex structures"



USES OF NANOMEDICINE

How can nanotechnology be applied to help fight disease and save lives?

In medicine, artificially created molecules the size of proteins, which are able to slip in and out of the blood stream and individual cells, could be an incredibly useful tool for delivering drugs throughout the body. Nanomotors could be used to direct helpful molecules to organs where they're needed. The choice of materials used to build these machines and structures also helps them to effectively achieve their function. Rings of carbon atoms – that assemble as long, thin nanotubes – provide strength and could be used as scaffolds to help repair bone, while nanoparticles filled with gold or silver can be used to destroy cancer cells or unwanted bacteria.

Fighting infection with nanoparticles

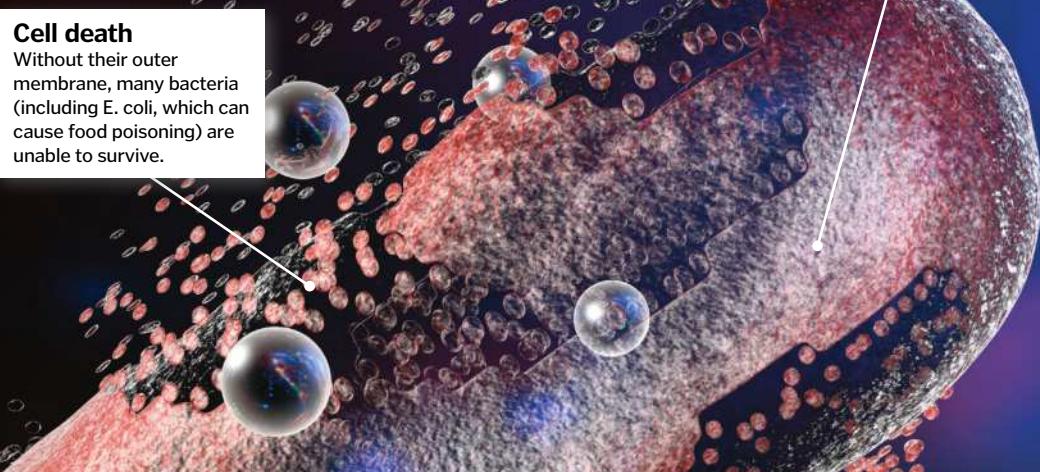
Silver ions are effective tools for killing bacteria

Silver ion

Silver has antimicrobial properties, and the element is often incorporated into medical dressings and equipment to help prevent and fight infections.

Cell death

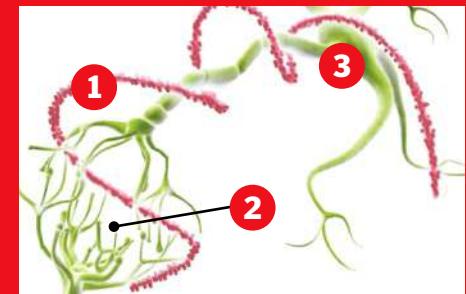
Without their outer membrane, many bacteria (including E. coli, which can cause food poisoning) are unable to survive.



Repairing nerve cells

Our central nervous systems are filled with neurons, which are organised in an expansive network to send information and instructions efficiently all around the body. The ability of neurons to be able to carry information is dependent on the electrical signals that are sent along and between them. If the neurons are damaged, the circuit is broken – and this is often irreparable.

Scientists are looking to carbon nanotubes for a way to repair this damage. By placing nanotubes in close contact with the neurons, they are able to act as a scaffold, consequently allowing the neurons to grow and reform connections. In the future, this could be used to develop treatments for neurological disorders such as Parkinson's.

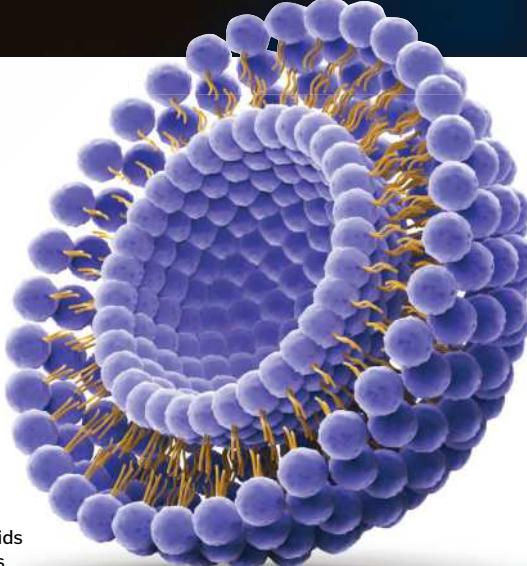


Drug delivery

Ensuring that therapeutic drugs reach their cell targets is no easy task when you're dealing with a complex organism like a human. Drugs may not arrive at the right destination, and those that do may not be able to enter the cells. The use of nanoparticles called liposomes – which are able to carry drugs into cells – may be a way to overcome this obstacle.

Liposomes surround the drug particles and help guide them to their destination. Once a liposome makes contact with a cell, it is slowly engulfed in a process called endocytosis. The liposome usually breaks down slowly inside the cell, but X-rays can be used to rupture the fatty layers more rapidly, so that they release their tiny parcels of drugs.

Liposomes are nanoscale 'bubbles' made of phospholipids – the same molecules that make up our cell membranes



Bacteria

Silver nanoparticles can destroy certain species of bacteria by interacting with their outer membranes, causing structural changes that make this protective layer degrade.

1 Nanotube mesh

Nanotubes occupy space around the neurons. This provides a scaffold for the neurons and helps to guide their growth.

2 Neuron connection

Neurons have to be close to one another to communicate. They can send chemical signals to each other across small gaps called synapses.

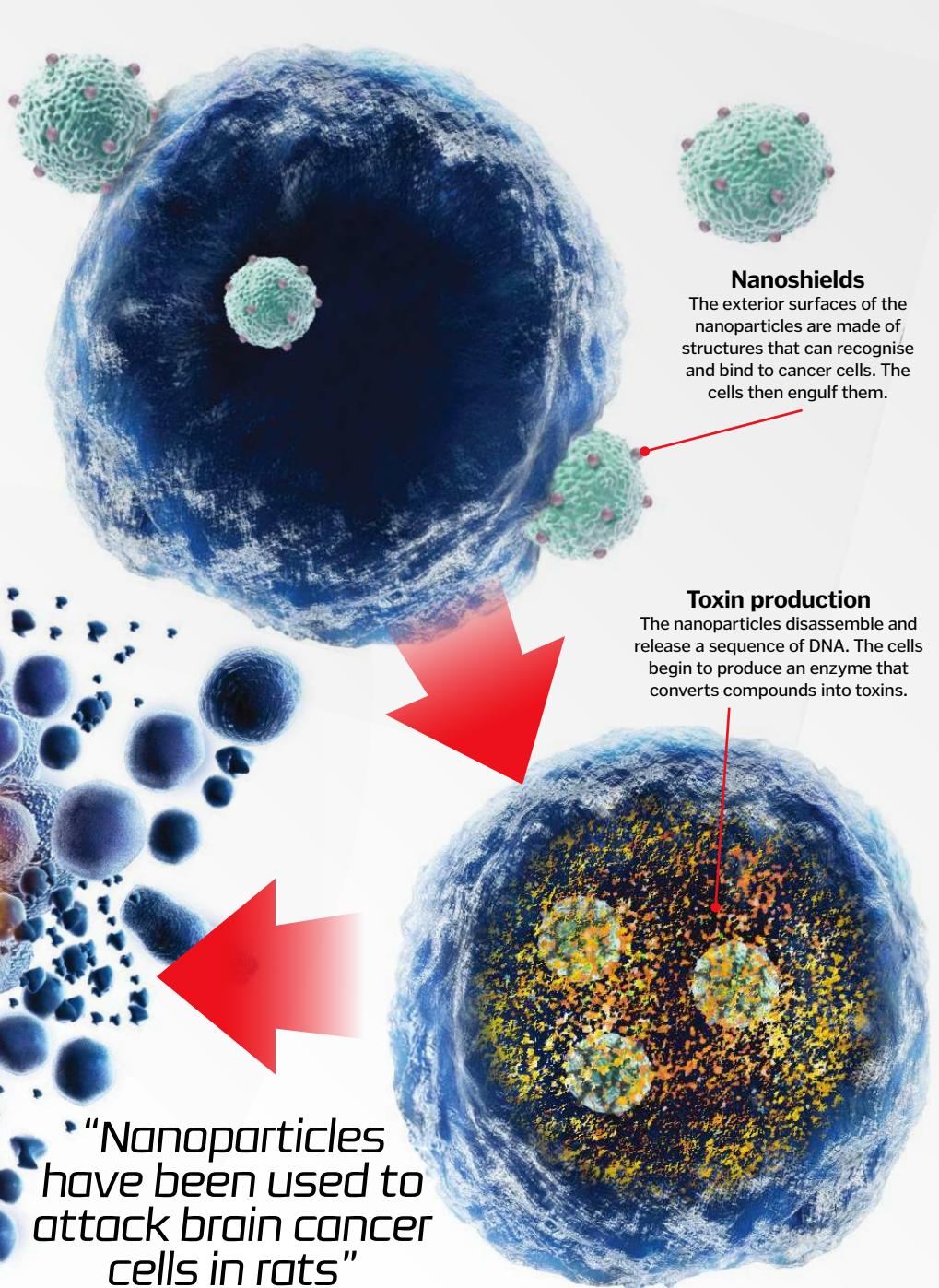
3 Regrowth

In the presence of the nanotubes, neurons can grow and re-establish contact with their neighbours.

Fighting cancer with nanoparticles

Surgery, chemotherapy and radiotherapy are currently the three main ways of treating cancer. Surgery to remove tumours can be very effective, but it is not suitable for all types of cancer. Chemotherapy is also highly effective at killing cells, but destroys them indiscriminately, attacking both cancerous and healthy tissue, which can leave patients with severe side effects. Radiotherapy can be targeted at a particular region, but also carries side effects and the risk of causing infertility.

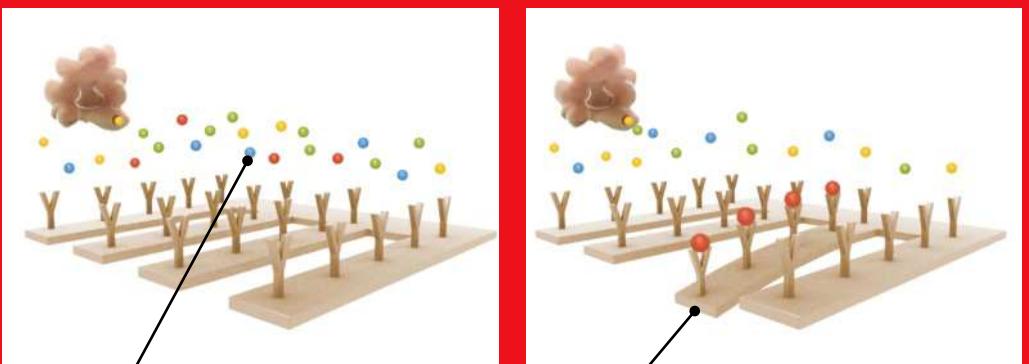
Nanoparticles could be used to carry a sequence of DNA into cancerous cells, resulting in the production of a toxic compound inside the cells that kills them. Nanoparticles like this have been successfully used in rats to attack brain cancer cells and shrink tumours, while leaving healthy tissue unharmed. It is hoped that the same technology could one day be used to fight the disease in humans, with few or perhaps even no negative side effects for the patient.



Detecting disease with nanocantilevers

Assembling structures on the molecular level can be very challenging, but one advantage is that small changes can have a large and detectable impact. In other words, adding single atoms or molecules can heavily influence their physical structure.

This idea has been used by scientists to create nanocantilevers. These nano-sized beams are covered in antibodies – small, Y-shaped proteins that recognise specific molecules. Cancer cells secrete molecules that bind to corresponding antibodies, forcing the beams to change shape. This concept could be used to quickly identify cancer in medical tests.



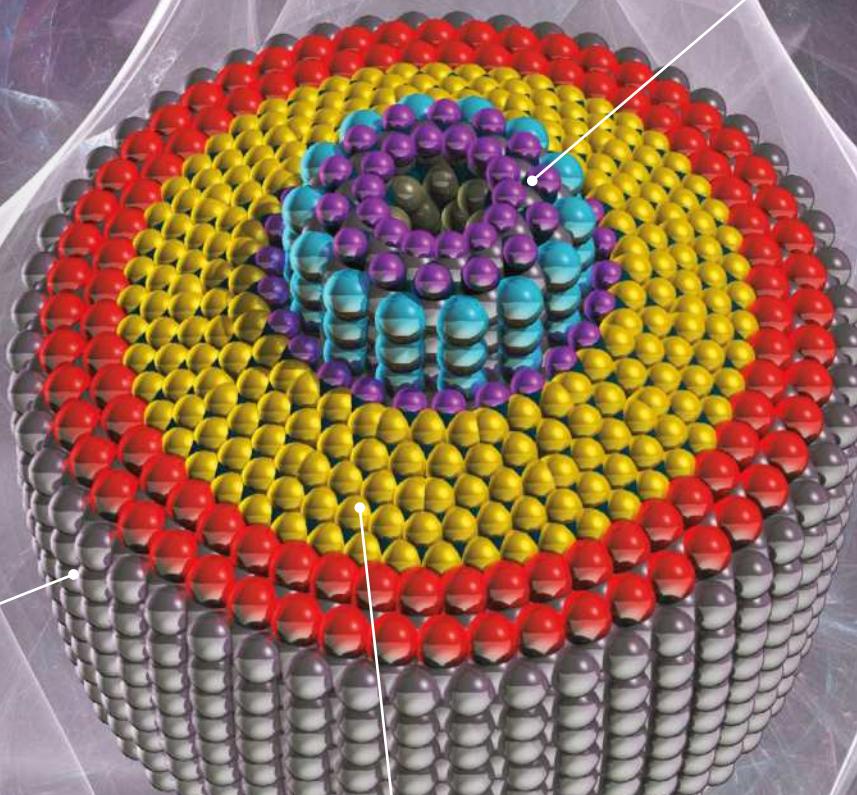
HOW TO BUILD A NANOBOT

Two methods are used to make things at the nanoscale: top-down or bottom-up

Assembling mini machines is no simple task, especially when we're talking about gears that only contain a few thousand atoms! Currently there are two quite different proposed methods of nanoconstruction: top-down and bottom-up. The top-down approach involves starting with a bulk of atoms and shaving away the parts you don't want, much like how a sculptor would carve away at a stone block until it assumed the form they wanted. Starting with a large amount of material makes this the more straightforward option, but every chunk that is cut away represents a considerable amount of waste, and the tools used for the task are so much larger than the final product that they are difficult to use accurately.

The alternative is the bottom-up approach, which is mostly still in the theoretical stage. This method involves building the nanobot atom by atom, or combining atoms in a way that lets them interact and self-assemble into the shape we want, which is of course quite complex! But when you're constructing controllable mechanical actions on the nanoscale, precision is everything, so the bottom-up approach will most likely take over in the future.

Bottom-up construction
Complex structures, such as this molecular gear, would only be able to achieve specific rotations if all the atomic parts were arranged very precisely, so bottom-up assembly would be required.



Assembly

A central column of atoms acts as an axle and is surrounded by other atoms that spin much like a wheel. The outer casing is formed of larger elements to reduce the number of atoms needed.

Moving atoms

If the outer casing is held still, the top central column can be rotated and used to spin the atoms between the shaft and external elements.

Everyday nanotech

It may seem futuristic, but nanotechnology is already here



Sunscreen

Zinc oxide and titanium dioxide are common ingredients in popular sun-protection products. Many modern lotions now use zinc oxide nanoparticles that are less visible on the skin than their larger counterparts.



Self-cleaning glass

A film of titanium dioxide just a few nanometres thick can be applied to sheets of glass, allowing the material to clean itself. The coating breaks down and loosens dirt, which is then washed away by rainwater.



Clothing

Antibacterial silver nanoparticles can be incorporated into certain fabrics that are used to make socks and sports clothing. These nanoparticles help to kill the bacteria that are responsible for sweaty smells.

How nanobots can be used to fight disease

The movie *Fantastic Voyage* told the story of a submarine holding a small crew that had been shrunk down so small they could be inserted into the bloodstream. Their mission: to clear a blood clot that was lurking inside their human host. The story seemed impossible at the time, but today we are busily working toward our own mini-medics to help heal us from the inside.

Medical nanobots are one of the most ambitious areas of nanotechnology. The aim is to create tiny,

controllable robots that can navigate through the bloodstream to reach places we currently find hard to reach, and repair damage without the need for invasive surgery. They could break down hard plaques found on arterial walls or clear blood clots in the brain.

Nanobots could perform surgery on individual cells, minimising the damage to healthy tissue



The future of nanomedicine

Nanobots could soon be roaming through our bloodstream and fixing unseen dangers

Cholesterol build-up

When an arterial wall is damaged, calcium, cholesterol and other components begin to build up and form hard plaques. If left unchecked, plaques can suddenly rupture with fatal consequences.

Plaque removal

The nanobot reduces the size of the plaque using flexible arms that bind to the individual components and separate them from the bulk.

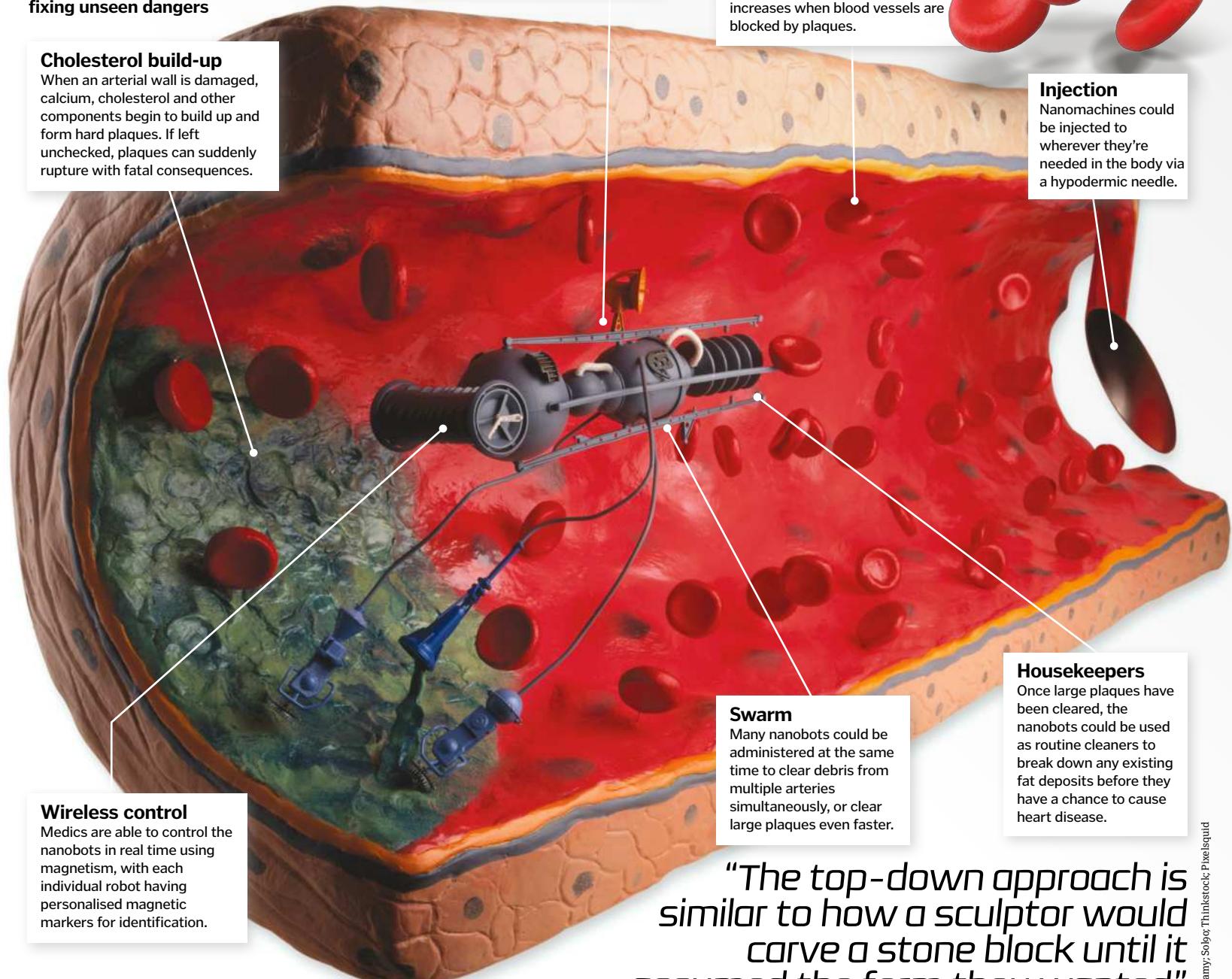
Blood flow

Red blood cells transport oxygen to tissues through the bloodstream. The force provided by the beating heart pushes the cells through arteries at high pressure, which increases when blood vessels are blocked by plaques.



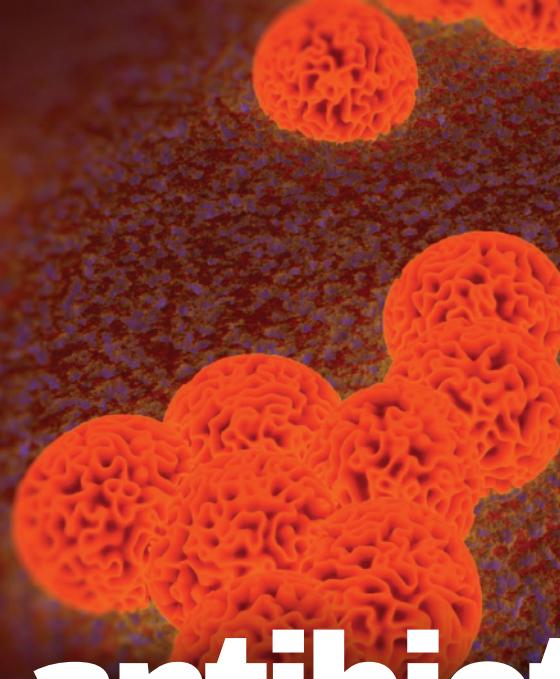
Injection

Nanomachines could be injected to wherever they're needed in the body via a hypodermic needle.



"The top-down approach is similar to how a sculptor would carve a stone block until it assumed the form they wanted"

MRSA, a *Staphylococcus aureus* strain, is resistant to many antibiotics



The antibiotic apocalypse

Are we heading towards a future where infections are immune to treatment?

We have a major problem. Since the dawn of humanity, we have been locked in a battle with microscopic organisms, and just when we thought we were starting to win, they're fighting back.

Bacteria cause some of the most devastating human diseases, from typhoid fever to tuberculosis, and until the 1920s, we were utterly defenceless. But when Alexander Fleming ushered in the age of the antibiotic with his discovery of penicillin, we suddenly had a powerful weapon.

Antibiotics work by stopping bacteria from dividing, or by killing them outright. Thanks to them we can treat infections that were once fatal, we can perform complex surgery, and we can mass-produce food on an unprecedented scale. But we have used them and used them and used them, and the bacteria have started to learn.

These little organisms can replicate in a matter of hours, and each time they do, they make tiny, accidental tweaks to their genetic

code. Some tweaks aren't useful, but very occasionally, a mistake is made that helps one bacterium to outlast an onslaught of antibiotics for just a little longer than their neighbours.

When the course of antibiotics are finished, and all of the vulnerable bacteria are dead, this slightly stronger individual can carry on dividing, making a new colony that are all a little bit better at avoiding the effects of the drugs. And if this happens time after time, you have a superbug on your hands.

Worse still, bacteria are able to share useful genes with their neighbours. And not just members of their own species. They carry useful snippets of genetic code in little rings of DNA called plasmids, and they can swap these like trading cards, passing resistance on to others around them.

Using these tactics, several strains of bacteria are now able to evade almost all of the antibiotics in our arsenal. We're in the middle of a microscopic arms race, and the future of medicine is hanging in the balance.



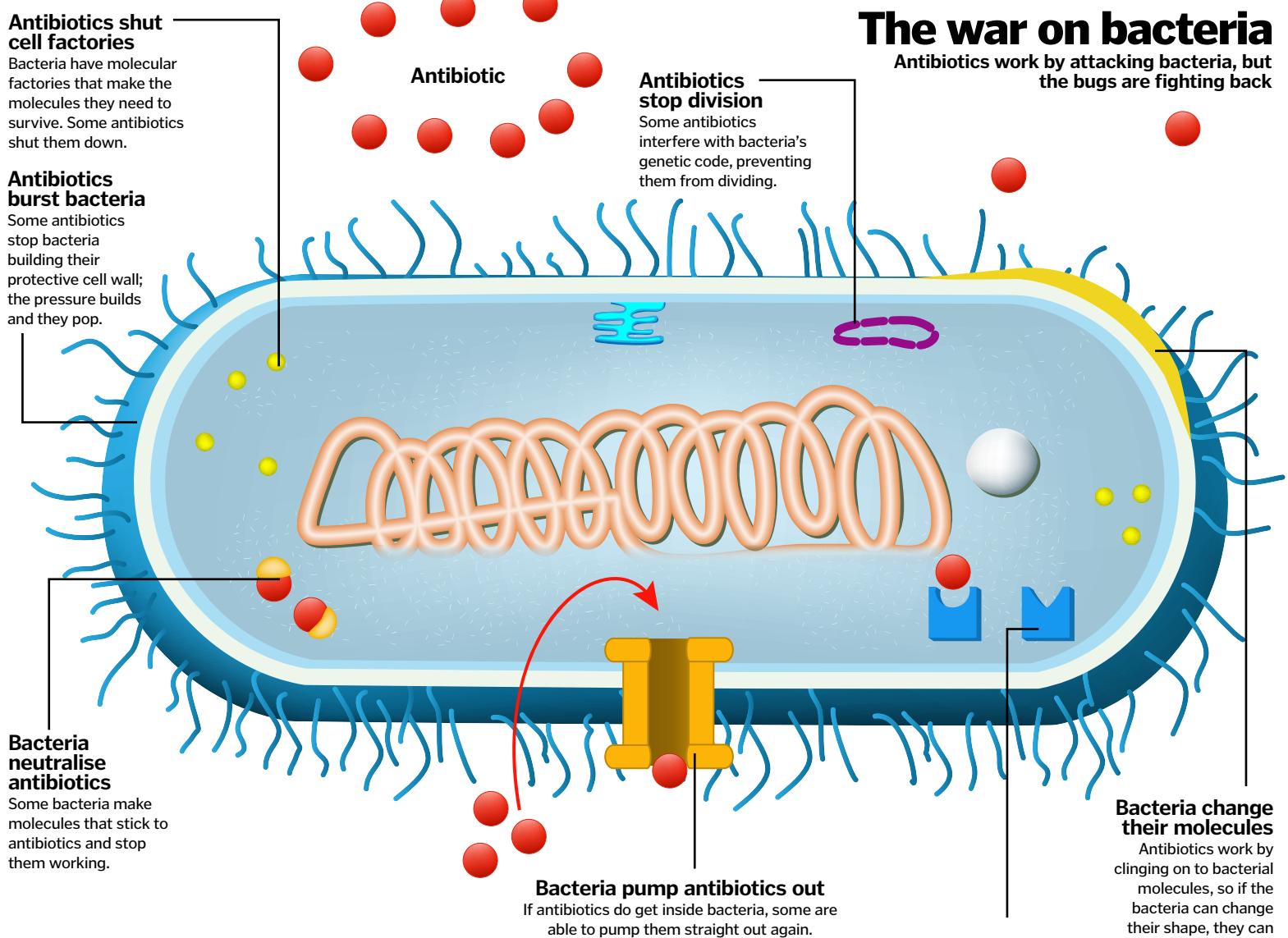
Antibiotics are used everywhere, from hospitals to intensive farms

What needs to be done?

Ensuring that effective antibiotics are available for future generations is a mammoth task. We need to stop giving bacteria the opportunity to see our best treatments.

Vets and doctors are being urged to only use antibiotics if absolutely necessary, and to test their patients beforehand to check that the treatment will definitely work to kill the infection. Patients are being asked to always finish their full course of antibiotics, even if they feel better, to ensure that any lurking bacteria have been cleared up. Farmers are being encouraged to keep their livestock clean and vaccinated rather than use antibiotics to control disease. Governments and development organisations are under pressure to regulate and monitor antibiotic use, and to make sure people have access to the right antibiotics. And the medical research community are racing to find new drugs to fight resistant strains.

Rather than throw antibiotics at any infection, we need to choose our battles carefully.



Superbug lineup



MRSA

Methicillin-resistant *Staphylococcus aureus* (MRSA) is the most infamous of all superbugs. Regular *Staphylococcus aureus* is a common type of bacteria, normally found harmlessly on the skin. This bug first started resisting the effects of antibiotics as far back as the 1950s, however, and MRSA itself first appeared in 1962.



VRE

Vancomycin-resistant *Enterococcus* (VRE) are immune to the effects of one of our most powerful antibiotics. Vancomycin is usually reserved for the most serious of infections, including meningitis and MRSA. These superbugs were first spotted in the 1980s, and have proven very good at developing resistance to any new antibiotics thrown at them.



MDR-TB

Multi-drug-resistant *Mycobacterium tuberculosis* (MDR-TB) does not respond to the two most powerful anti-tuberculosis drugs currently available - rifampicin and isoniazid. Normal treatment for TB involves a combination of antibiotics taken for 6 months, but if the drugs are given alone, or stopped too soon, resistance can develop.



KPC

Klebsiella pneumoniae carbapenemase-producing bacteria (KPC) are a relatively new problem, first identified in the USA in the early 2000s. They are very good at resisting treatment, and also produce an enzyme that allows them to break down carbapenem, a powerful antibiotic that's one of our last lines of defence.



Learn more

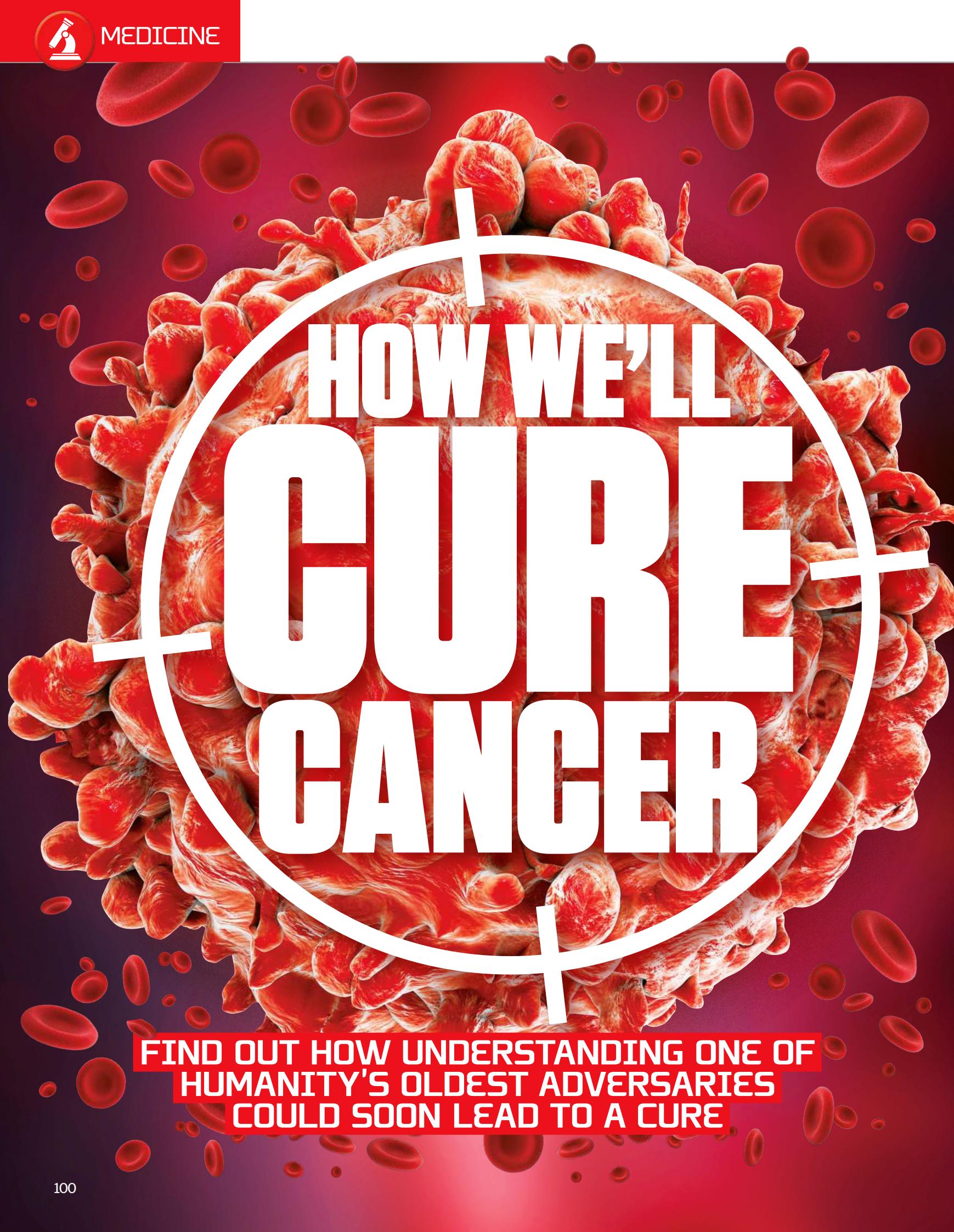
Arm yourself with information

Knowledge is the most powerful weapon we have against an antibiotic apocalypse, here are two top places to learn more:

- **The World Health Organisation**
www.who.int

Working in over 150 countries, the World Health Organisation are leading the fight against antibiotic resistance. Their social media accounts are a great place for bite-sized news and updates.

- **Bugs and Drugs**
www.antibioticresistance.org.uk
- With funding from the British Government's Department of Health, the National Electronic Library of Infection have made a one-stop hub of information about antibiotic resistance.



FIND OUT HOW UNDERSTANDING ONE OF
HUMANITY'S OLDEST ADVERSARIES
COULD SOON LEAD TO A CURE

Cancer has been around longer than we have. Traces have been found in 70 million-year-old dinosaur bones, in a 120,000-year-old Neanderthal rib, and in a human skeleton dating back to 1200 BCE. And almost every animal, even sharks and naked mole rats, can get the disease.

It was once untreatable. Ancient Roman doctor Celsus wrote, "After excision, even when a scar has formed, none the less the disease has returned." Even if the tumours were removed, they kept coming back, but in ancient times we didn't fully understand exactly what we were up against.

By the 17th century, physicians were pointing the finger at a straw-coloured liquid called lymph, which passes through the body in channels that run alongside the blood vessels. And by the mid-1800s, it became clear that cancers were actually made from cells.

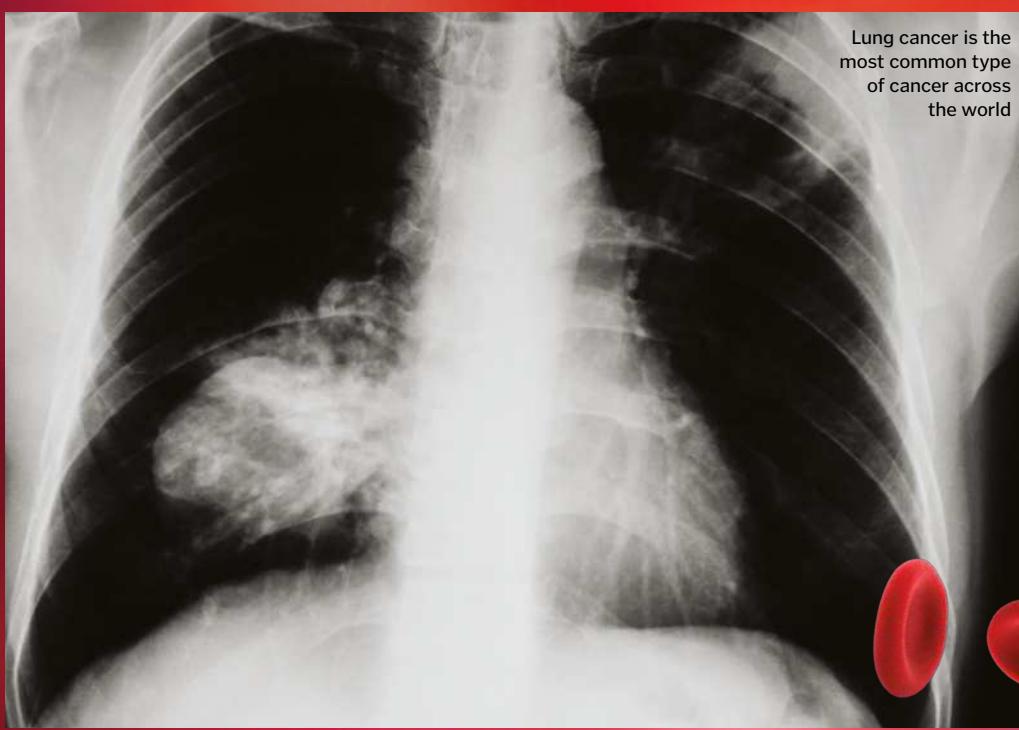
Realising that cancer spread from the original tumour, 19th-century surgeons, with the help of new anaesthetics, started removing more tissue and nearby lymph nodes. Then, at the start of the 20th century, radiotherapy became available to treat irremovable cancers. Nitrogen mustards then became the first chemotherapy drugs after WWI.

Then a massive breakthrough was made. In 1953, James Watson and Francis Crick deciphered the structure of DNA, opening the door to a new era of genetic science. We now know that tumours are made of our own cells but their genes have gone wrong. They change constantly, they evolve to escape treatments, and they hide and spread undetected. And the more we learn, the more we are unravelling their weaknesses.

A century ago a cure for cancer would have been unthinkable, but as research continues survival is rising, and there are many more discoveries yet to be made.



Damage builds up in our DNA over time, making cancer more common in older people



Cancer statistics

14 million

people were diagnosed with cancer in 2012

22%

of cancer deaths are caused by smoking

8.2 million

people died from cancer in 2012

70%

of cancers happen in low and middle income countries

Cancer is the second highest cause of death in the world

Up to half of all cancers can be prevented by lifestyle changes

Lung cancer is the most common worldwide, followed by breast and colon

The UK has the 23rd highest cancer rate in the world



What is cancer?

The first step to finding a cure is understanding exactly what we're up against

You're made up of an estimated 37.2 trillion cells, each containing an entire copy of your DNA, which consists of 23 pairs of chromosomes and 21,000 genes, written in combinations of four chemical 'letters': A, C, G and T.

The full human DNA sequence contains around 3 billion letters, and the genes are arranged into three-letter 'words' called codons. Each word corresponds to a molecular building block called an amino acid and, when genes are read in order, the words in a gene provide the

recipe to build a protein. Proteins are crucial for everything that a cell does, from making energy to deciding when to divide to communicating with its neighbours. But in cancer cells vital genes contain mistakes, changing their proteins and altering the way that they behave.

It takes lots of genetic mistakes to turn a healthy cell into a cancer cell, and they tend to build up over time. A few people inherit genetic faults from their parents, but most occur as we get older. Sunlight, alcohol, radiation and

smoking, for example, can all cause harm to our genetic code. But even people with the healthiest lifestyles accumulate genetic faults.

Cells divide for growth and repair, making copies of themselves to replace old cells or to heal wounds. In order to do this, a cell must first duplicate all 3 billion letters of its DNA, and doing this without making a single mistake is a virtually impossible task.

The copied code is scanned for errors, and mistakes are usually fixed before the cell

"Cancer cells keep making copies of themselves with more mistakes"

They change their metabolism
Cancer cells reprogram their metabolism to keep dividing under conditions that would normally kill other cells.

They resist death
Healthy cells self-destruct when they are damaged, but cancer cells turn this safety switch off.

They mutate
Cancer cells accumulate more and more mutations as they continue to divide.

Cancer cells are immortal. Cells like these have been growing continuously in labs since the 1950s

They keep growing
Cells normally wait for a signal to divide, but cancer cells make their own growth signals.

They don't stop when told
Cancer cells ignore signals telling them to stop dividing.

They avoid white blood cells
Cancer cells hide from the immune system, preventing the body's natural defences from killing them.

They are immortal
Normal cells stop dividing when they become old, but cancer cells keep on replicating indefinitely.

The hallmarks of cancer

Scientists Douglas Hanahan and Robert Weinberg defined ten distinctive features of cancer cells

They set up fuel lines
As tumours grow, they get more oxygen and nutrients by encouraging new blood vessels to form.

They spread
Cancer cells can spread around the body, creating more tumours in other places.

They create inflammation
Cancer cells hijack immune cells, using inflammation that would normally help to fight against an infection to their own advantage.

divides, but sometimes errors slip through and over time they start to build up.

Just as changing the letters in a book would make the words unreadable, changing the letters in the genetic code makes it hard for the cell to make sense of its genes. If letters are changed, deleted, added or moved around, it can completely change the meaning of the genetic words, which in turn changes the proteins that the cell makes.

Built-in safety mechanisms normally tell a cell to self-destruct if it has too many genetic errors, allowing a new, healthy cell to take its place. But sometimes damaged cells slip through the net, failing to repair themselves and resisting the signals to die.

Cancer cells tend to have errors in genes known as 'oncogenes' or 'tumour suppressor genes'. Oncogenes are normally responsible for telling healthy cells to divide, helping with growth and wound repair, but mutations in cancer can cause them to become permanently switched on. Tumour suppressor genes, on the other hand, tell cells to stop dividing once growth or repair is completed, and errors in these genes can cause them to turn off. The result is that the damaged cells divide and divide and divide, piling up on top of each other to form a tumour.

With their safety systems switched off and nothing to tell them to stop, cancer cells keep making copies of themselves with more

mistakes in their genetic code, and this leads to Darwinian evolution at a rapid speed. Just as if a wild animal has a beneficial genetic trait it will be more likely to reproduce, if a cancer cell has a beneficial trait it will be more likely to survive.

Cancer cells forget what they are supposed to be doing and gain new abilities, developing traits that allow them to hide from the immune system, survive on less oxygen, and even evade chemotherapy. But, most dangerous of all, they gain the ability to move through the body, spreading to distant places via the blood or lymphatic systems and making new tumours elsewhere. But the more we understand about how cancer works, the better we are becoming at treating it.

How cancer starts

Cancer begins with a single mutated cell that divides and spreads

Cancer cell

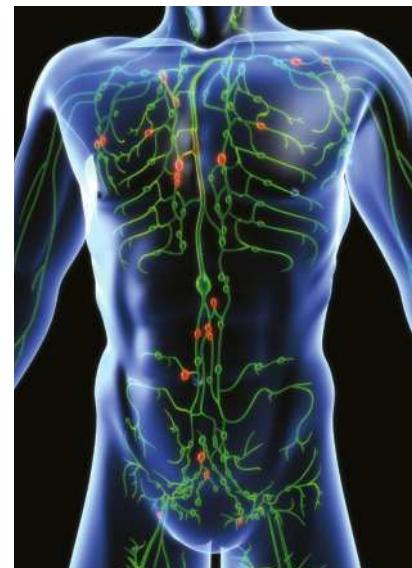
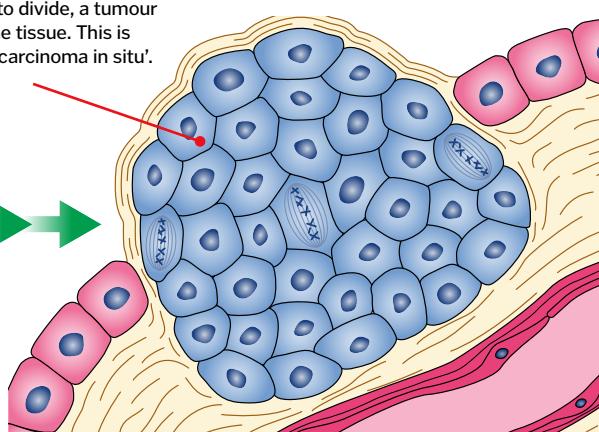
Genetic errors inside the cell tell it to keep making copies of itself.

Tumour

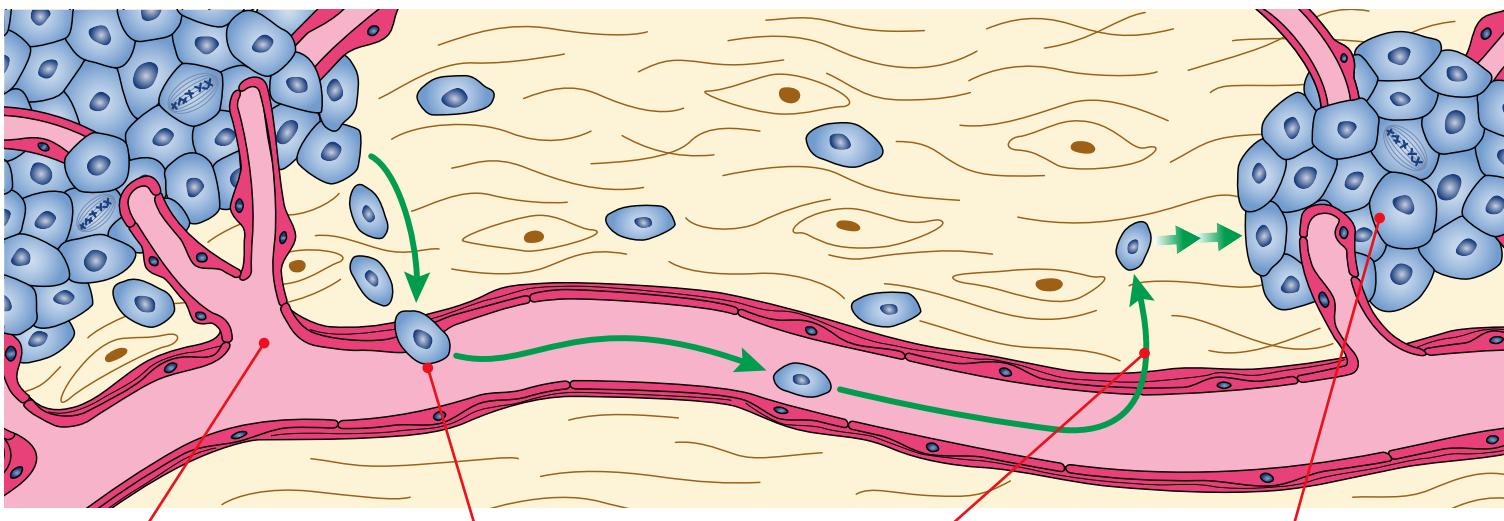
As the abnormal cell continues to divide, a tumour forms in the tissue. This is known as 'carcinoma in situ'.

Normal cell

Most cancers begin when a normal cell lining one of the body's organs goes wrong.



Cancer cells can use the lymphatic system to spread around the body



Blood vessels

To keep growing the tumour needs a blood supply, so it encourages the formation of new blood vessels.

Distant spread

Cells start to break away from the main tumour, entering the lymphatic system and the blood vessels and spreading around the body.

Local spread

Eventually, the tumour starts to invade the local tissue, growing down into the connective tissue below.

Secondary tumour

Cancer cells become lodged in different tissues and continue growing, forming more tumours known as 'secondaries' or 'metastases'.

Treating cancer

There are three major types of cancer treatment: surgery, radiotherapy and chemotherapy

Chemotherapy

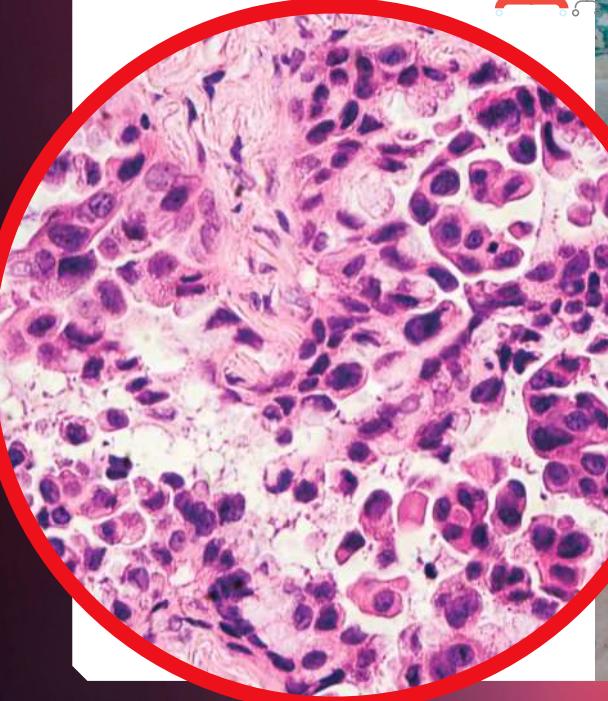
The first chemotherapy drug was developed using mustard gas, a chemical weapon used during WWI. Scientists had noticed that the poison killed the fast-dividing cells of the bone marrow, and so they adjusted the weapon to make nitrogen mustard, a treatment that could kill rapidly replicating cancer cells.

Nitrogen mustard belongs to a group of drugs known as alkylating agents, which work by adding chemical units called alkyl groups to DNA. These interfere with the double helix structure, causing the genetic code to break apart.

Other chemotherapies work in similar ways. Heavy metals cross-link DNA, preventing it from being read. Topoisomerase inhibitors stop the DNA helix from unwinding, and antimetabolites work by mimicking molecules involved in copying DNA, stopping the new sequence from being made. Anti-microtubule, or spindle poisons, stop cells from splitting apart, and cytotoxic antibiotics stick to the DNA helix, prevent unwinding, link different strands of DNA together or break DNA into fragments.

These treatments are particularly harmful to cells that are trying to make copies of themselves because they target DNA replication and cell division. This is good for catching fast-dividing cancer cells, but it isn't perfect. Cancer cells aren't always dividing, so some cells manage to escape the treatment, and lots of healthy cells also divide rapidly, too. Hair, skin and bone marrow (which makes blood cells) are all damaged by chemotherapy, leading to side-effects like hair loss, sickness and a weakened immune system.

Pathologists examine images like these to diagnose cancer. This lung tissue should be full of holes



Chemotherapies harm cells that are trying to divide



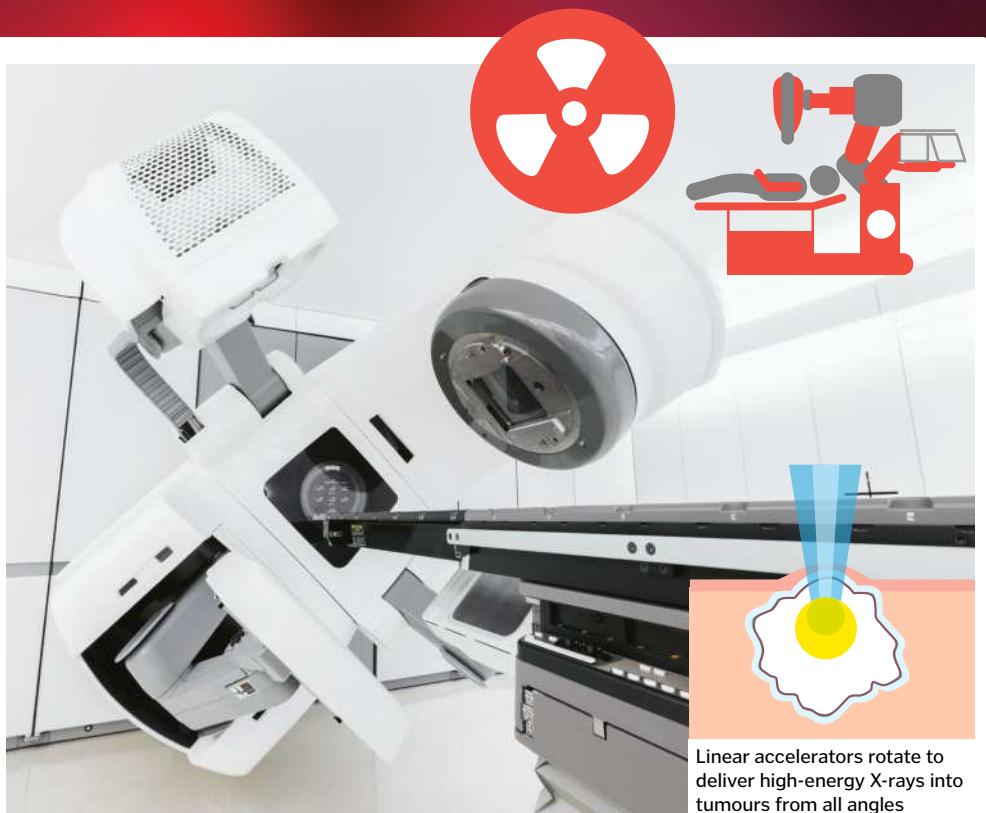
Radiotherapy

Radiotherapy was developed in the early 20th century and works by bombarding cancer cells with radiation. When the water molecules inside the cells are hit they split apart in a process called radiolysis. This makes highly reactive free radicals with an unpaired electron that attacks bonds belonging to other molecules, setting off a chain reaction that damages DNA.

Radiotherapy causes both strands of the DNA to break close together, a lesion known as a 'double-strand' break. This makes the helix unstable and it starts to unwind. Cells can repair a bit of this kind of damage, but the more radiation they receive, the more likely they are to die.

The most common way to deliver radiotherapy is by using a linear accelerator (LINAC). It uses microwaves to make electrons, which hit a heavy metal to make X-rays. CT or MRI scans are used to pinpoint the exact location of the tumour inside the body, and the X-rays are then shaped to fit the outline of the tumour. This is done by blocking part of the beam using sheets of metal known as a multileaf collimator.

X-rays go all the way through the body, so the machine rotates to deliver beams from all angles, giving the maximum dose where the beams cross over at the site of the tumour, minimising the amount of radiation received by the surrounding healthy tissue.



Surgery

Surgery is one of the oldest and most effective cancer treatments. If the cancer hasn't spread, surgeons take out the whole tumour and some of the surrounding area in case there are any cells that can't be seen. Nearby lymph nodes may also be removed as these are often the first place a cancer will spread to.

If the whole tumour cannot be removed, surgery can also be used for 'debulking', where as much of the tumour is removed as possible so the rest can be treated with chemotherapy or radiotherapy. Surgery can also be palliative, relieving symptoms when cancer cannot be cured.

Not all lumps are tumours and not all tumours are cancer, so surgery is often used for cancer diagnosis, too. A small sample of tissue, known as a biopsy, is removed and either frozen solid or embedded in wax so that it can be thinly sliced. These slices are stained so that a pathologist can examine the structure of the cells and tissue.

Cancer cells look different under a microscope, creating disorganised structures in normally orderly tissues, and they also display specific molecular or genetic markers that single them out. These not only help with a cancer diagnosis but can also be used to determine the type of cancer, how advanced it is and the best form of treatment to use against it.



The future of cancer treatment

The more we learn about cancer, the better we are able to target its weaknesses

In the UK, overall cancer survival is now at 50 per cent, and ten-year survival for testicular cancer has reached an impressive 98 per cent. But there's still a way to go. There are hundreds of different types of cancer, and even patients with the same cancer type have subtle differences in their tumours that change their response to treatment. Cancers can become resistant to chemotherapy and radiotherapy, and many treatments also harm healthy cells, causing side-effects that limit their use.

Until recently, most cancer treatments have focused on one thing: cell division. Both radiotherapy and chemotherapy hit rapidly dividing cells, damaging their DNA as they try to replicate, causing them to die. But cancer has lots of other weaknesses and scientists are attacking from all angles, using the latest tech to reveal their genetic and molecular differences.

One tactic is to cut cancer's fuel lines. As tumours grow and cells pile on top of one another, oxygen levels drop and the cancer cells encourage new blood vessel cells to break down tissue and migrate in. Blocking this process could stop tumour growth in its tracks.

Another option is to use the immune system, helping our own cells to see cancer cells and destroy them. Techniques being trialled include using molecules to block the interaction between cancer cells and immune cells, preventing the tumour from switching the immune system off, and genetically engineering immune cells to supercharge their ability to seek and destroy cancer cells.

Immune molecules called antibodies are also being transformed into highly targeted cancer treatments that should leave healthy cells unharmed. They can be made to stick specifically to a single molecule, blocking the chemical signals that tumours need to survive or attaching directly to the cancer cells. They can even be linked to chemotherapy or radiotherapy molecules, delivering a double hit of toxin and immune attack.

Researchers are also working on genetically modifying viruses to infect and kill cancer cells, delivering drugs into cancer cells using nanoparticles and designing small molecules to interfere with the crucial molecular machinery that cancer cells use to survive.

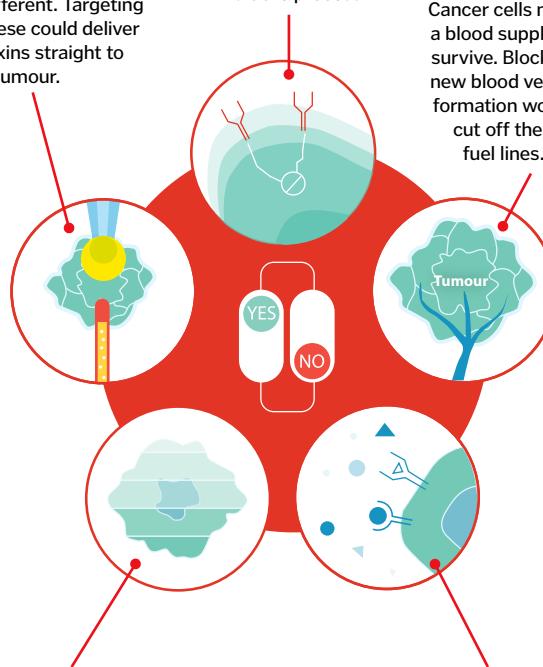
It's very unlikely that there will ever be a single cancer cure, but the more we learn, the more targeted treatments will become, killing cancer cells more effectively and leaving healthy cells unharmed.

Targeting cancer's weaknesses

Modern techniques are zeroing in on the molecules and genetics that make cancer cells vulnerable

Molecular tags

Cancer cell molecules look different. Targeting these could deliver toxins straight to a tumour.



Self-destruction

Cancer cells don't die even though they are faulty. Targeted therapies could switch self-destruct systems on.

Growth signals

Cancer cells receive signals that tell them to keep growing. Blocking these could halt the process.

Blood supply

Cancer cells need a blood supply to survive. Blocking new blood vessel formation would cut off their fuel lines.

Trawling cancer genetics

Cancers have distinctive mistakes in their genetic code that could reveal weaknesses.



Pathology

Cancer cells can be tested for the presence of molecules that single them out as defective.



Custom treatment

Individual patients could be matched to the treatments most likely to work for their unique tumour.



Customising cancer treatment

The Human Genome Project unravelled the human genetic code in 2003. This epic sequencing mission detailed every single letter of our DNA, revealing for the first time the complete recipe book for a human body. Cancer cells read from the same recipe book as healthy cells, just with words blotted out, pages stuck together and sentences scrambled. By understanding how the recipe book is supposed to be put together, scientists are now better able to identify why and how cancer cells have got it so badly wrong.

Every person is slightly different and their cancer cells start with a slightly different set of instructions, and as the disease progresses, different tumours adapt in different ways. Two women might both have breast cancer, but although there are patterns of similarity, the

genetics inside their cancer cells won't be exactly the same, so they don't always respond in the same way to treatment. In the future, people will be tested to reveal the targeted treatments that will work best for them.



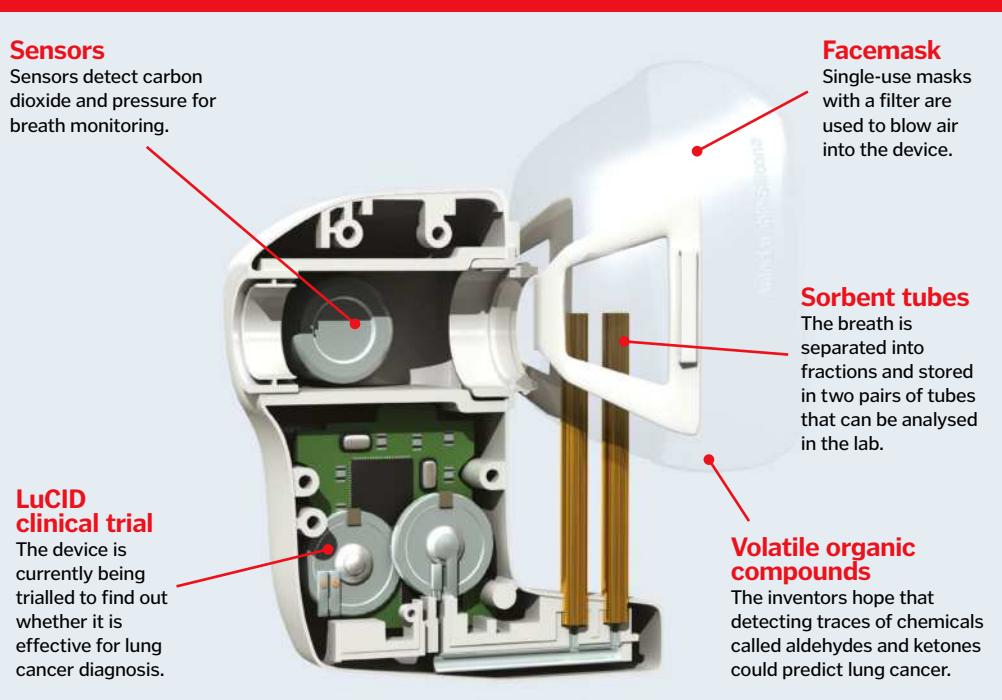
Different cancers carry different mistakes and respond differently to treatment

Catching cancer early

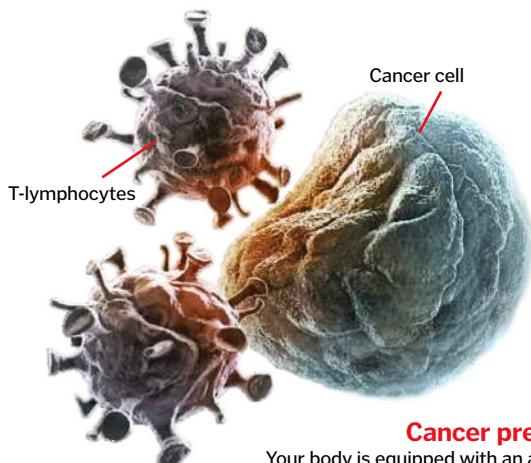
The sooner cancer is detected, the easier it is to treat. There are already three screening programmes in operation in the UK to detect bowel cancer, breast cancer and cervical cancer, but in the future things could become a whole lot simpler. Research into 'biomarkers' is searching for molecular signals that could reveal cancer in a simple blood, urine or even breath test.

Biomarkers are molecular signatures unique to different types of cells. Cancer cells differ from normal cells in ways that can already be detected using biopsies of tumour tissue, but researchers think that these differences might also make their way into body fluids, allowing them to be picked up with a simple test. Biomarkers might be able to reveal clues about the best treatment to use, whether the tumour is becoming resistant to current drugs and whether cancer has returned.

"One tactic is to cut cancer's fuel lines"

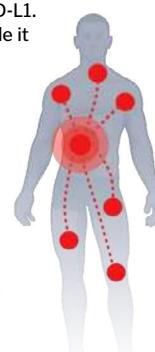
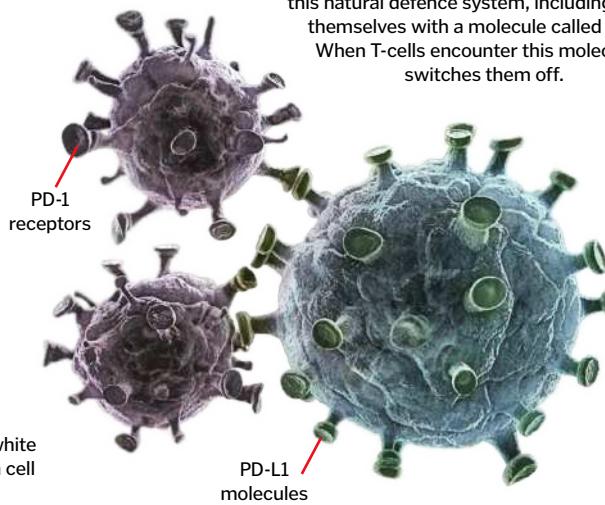


Strengthening your immune army



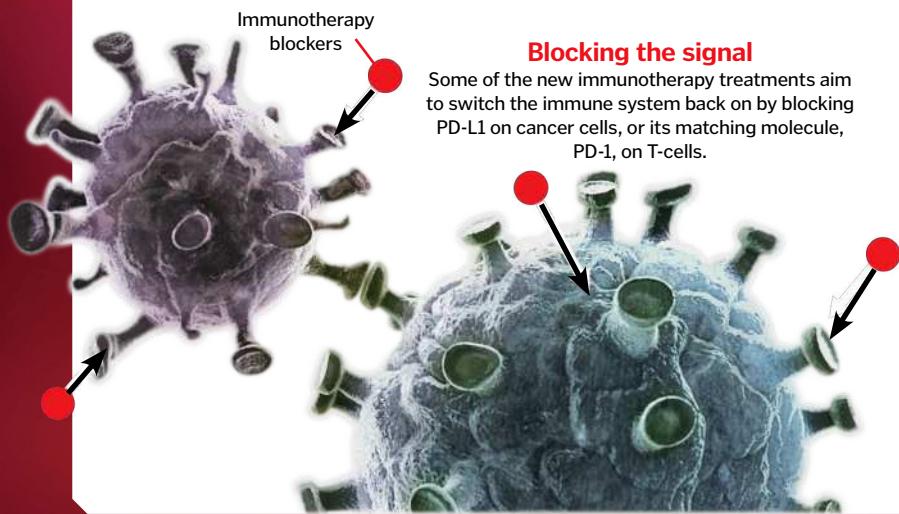
Cancer prevention

Your body is equipped with an army of 'killer' T-cells: white blood cells that patrol the body looking for trouble. If a cell starts to go wrong, these cells come in and kill it.



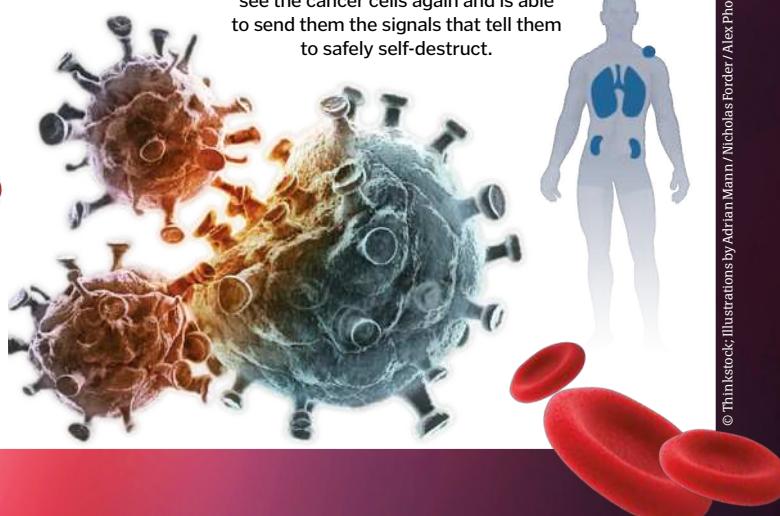
Subterfuge

Cancer cells develop different ways to evade this natural defence system, including coating themselves with a molecule called PD-L1. When T-cells encounter this molecule it switches them off.



Blocking the signal

Some of the new immunotherapy treatments aim to switch the immune system back on by blocking PD-L1 on cancer cells, or its matching molecule, PD-1, on T-cells.



The immune system is then able to see the cancer cells again and is able to send them the signals that tell them to safely self-destruct.

Expert opinion

How It Works spoke to an immunologist and a research nurse about the future of cancer treatment

The immunologist

Dr Edd James is an associate professor in cancer immunology at the University of Southampton, one of the country's leading centres for immunotherapy research



Could you tell us a bit about your research? What are you trying to find out?

The immune system, in particular the 'infantry' known as killer T-cells, are able to detect cancer cells through examining small protein fragments presented on larger proteins called MHC at the surface of cells. Almost all cells have these MHC molecules and they act as a way to understand what is going on in the cell at that moment. Despite these molecules, cancer cells are able to 'hide in plain sight'

Edd is trying to help killer T-cells to see cancer cells

from the killer T-cells. We are investigating how they do this and how to either reverse this process or re-educate the killer T-cells to be able to 'see' the cancer cells through changing what the MHC molecules show them.

Why can't the immune system just kill cancer cells on its own?

In many instances, the immune system does kill cancer cells at an early stage of development without us knowing about it. However, cancer cells 'evolve' to hide themselves to prevent the immune system from finding and attacking them. In addition, the cancer cells are able to promote an environment that suppresses the immune response, thus preventing it from working properly.

How does immunotherapy help?

Immunotherapy works in many ways, but there are two main methods by which it can help. The first is to target molecules that the cancer cells have on the cell surface using proteins called antibodies. These are specific for particular molecules and once bound to the target molecules serve to highlight the targeted cancer cells to the immune system. This allows them to be identified, attacked and destroyed.

The second method is to target the killer T-cells themselves. Cancer cells are able to put the brakes on the killer T-cells to prevent them working properly. This occurs because the cancer cells deliver a negative, inhibitory signal to the killer T-cells through interaction. These signals are produced through a number of different molecules that can be blocked using antibodies. Blocking these interactions

prevents the negative signals and allows the killer T-cells to work normally and kill the cancer cells.

What needs to be done next to make immunotherapy better?

Currently the therapies that are used are relatively blunt tools and aren't effective in many people. We need to understand how the cancer blocks the immune system in greater detail. This will give us a better appreciation of the processes involved in allowing cancer cells to evade the immune system and also allow us to identify new molecules to target.

There are many new investigations looking to combine current immunotherapies to improve their success. In trials these are working much better. However, a major downside of many of these combinations is an increase in side-effects that needs to be addressed.

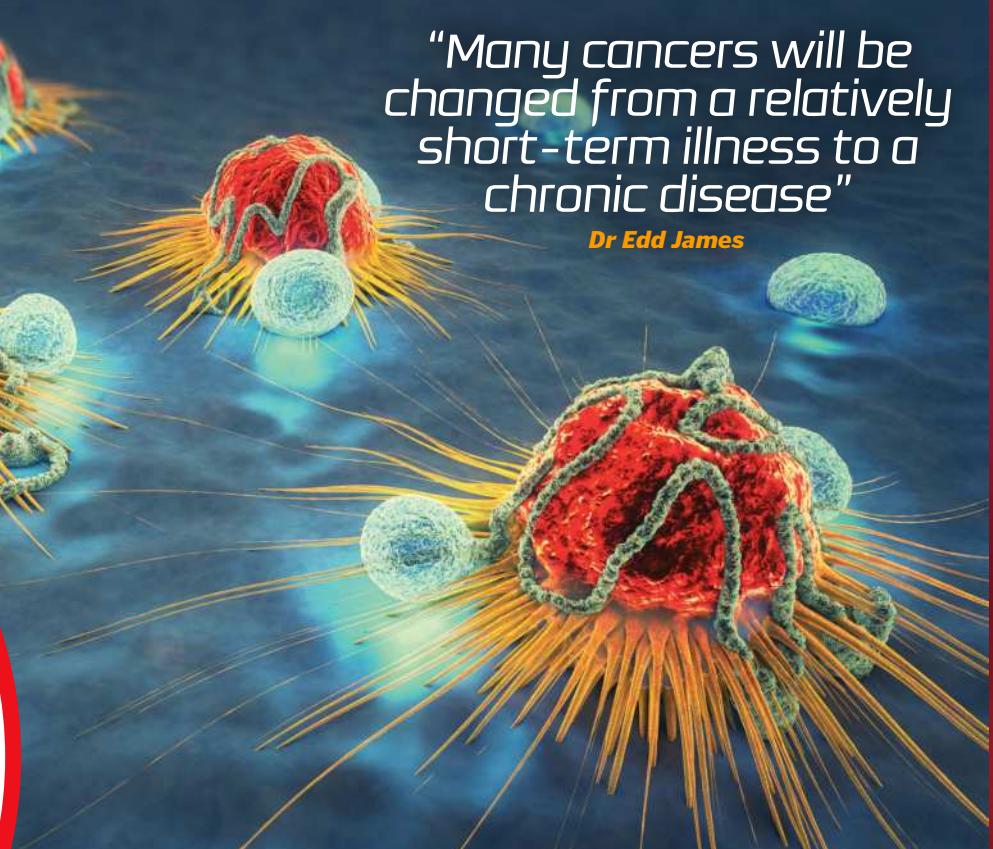
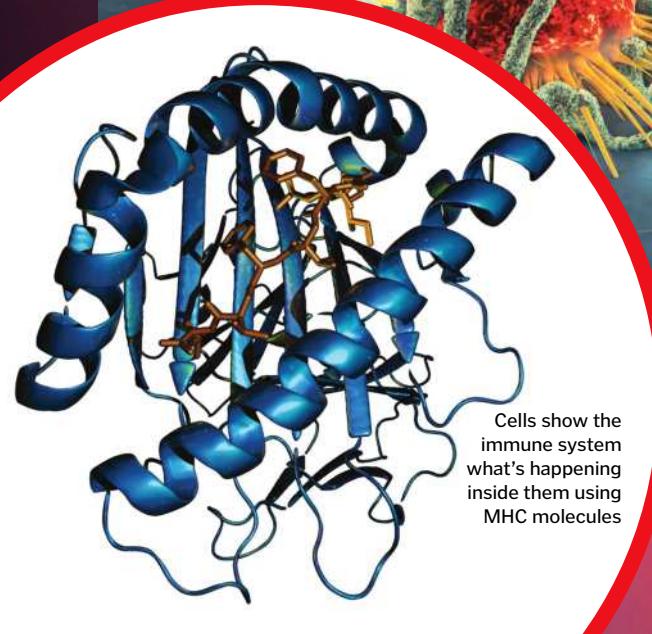
Do you think we will ever cure cancer?

There is likely to be an effective cure for a number of cancers in the future. Our greater understanding of the molecular aspects of a cancer, and how to utilise the immune system more effectively to kill the cancer, will greatly increase possible treatments and improve their efficacy. This will allow a much more personalised approach to treatment based on the molecular characteristics of the cancer.

These advances will mean that many cancers will be changed from a relatively short-term illness to a chronic disease, where patients are treated as and when cancer arises. This will increase cancer-free survival, effectively enabling many people to live a normal lifespan.

"Many cancers will be changed from a relatively short-term illness to a chronic disease"

Dr Edd James



The research nurse

Jac Samuel is a CRUK senior research nurse. She leads a team of research nurses delivering clinical trials testing brand new cancer treatments for the first time



Could you explain a bit about what research nursing is?

Research nursing is a really interesting career pathway, which most nurses when they qualify don't even consider. You think you're going to work on a ward, and you obviously go into nursing because you want to look after people and help them. Research nursing is interesting because you're working with new treatments that are not licensed.

It's a process of gathering data, which is then analysed to see whether or not this new treatment is comparably better than what we've currently got. It might be that it works better, or it might be that it doesn't work any better but it doesn't have such bad side-effects. Or maybe, instead of giving it via somebody's vein, they might be able to take it in the form of a tablet.

As a research nurse you're delivering those treatments to patients. We don't know how well it works, so we're conducting an investigation. What we're aiming for is really good quality data that can be analysed to prove how well something is working.

Why do treatments have to go through trials?

You can't just give something from a lab because you don't know how it works. Even if it's worked in an animal model, you don't know how it's going to work in a human. Everything has to be tested to make sure it's safe. Otherwise you could have some company saying, 'Hey, we think this really works and it's a cure, and we're going to charge you £50,000 for it' but there would be no evidence for that.

The whole point of research is that it's evidence-based. The laboratories will create the treatment,

and they will test it in a cell line and in an animal model, but it's very different to how it might work in a human.

What changes have you seen in cancer treatment?

I've been nursing for a long time now, but even in the last five years actually it has really changed. Scientists have so much more understanding now of the intricacies of cells. Before, there used to be a blanket term for several different sorts of cancer. It's so much more nuanced now, and I think this is only the tip of the iceberg.

There have been certain drugs that have turned it around for patients. Five or ten years ago, you knew with their diagnosis that their prognosis was not great, and yet now you're seeing patients with exactly the same type of disease out of treatment and going strong.

Do you think that there will ever be a cure for cancer?

I think it's really difficult to say that there is going to be one single cure for cancer. The trouble is cancer is such an umbrella term. You've got so many different sorts of cells in your body, and cancer can affect different types of cells in different ways.

I think that as we've seen such a big change in survival rates in the last ten or 15 years, in the next ten or 15 years you're going to see big breakthroughs that are going to make huge differences. We still don't have a cure for cancer, but more people are surviving cancer and their quality of life is better with their treatment, and I think that will continue.

Information and support

For more information about cancer from the NHS visit

www.nhs.uk/Conditions/Cancer/Pages/Introduction.aspx

If you have questions about cancer, you can contact Cancer Research UK's nurses helpline on 0808 800 4040 Monday to Friday 9am to 5pm.

Need to talk? You can contact Macmillan Cancer Support on 0808 808 00 00 Monday to Friday 9am to 8pm.

If you want to find out more about cancer treatments, Cancer Research UK and FutureLearn have a free online course at www.futurelearn.com/courses/targeted-cancer-treatments



Jac's team of research nurses deliver experimental drugs in clinical trials



SPACE

120

Farming on
alien planets



114

Spaceport
America



122 A home
from home



122

Living on the Moon?



112

Path of the Osiris Rex

112 Osiris Rex

This mission will bring back a chunk of asteroid

114 Inside Spaceport America

Take a peek at the world's first commercial spaceport

116 Remote-controlled explorers

How robot avatars could take us to new worlds without us having to leave Earth

120 Farming on alien planets

How could agriculture survive on other planets?

121 Rockets of past, present and future

Take a look at how far space travel has come

122 Living on the Moon

Discover the pros and cons about Moon colonies

121

Rockets of the future



OSIRIS-REx

How this mission will return a chunk of asteroid to Earth

Since the final Luna mission to the Moon in 1976, we have returned less than a gram of material from another celestial body to Earth. That's quite a shocking statistic if you think about it, but in 2023, it's all set to change.

NASA's OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer) will return the largest extraterrestrial sample to Earth since the Apollo missions, from an asteroid located beyond the orbit of Mars. Launched on 8 September 2016 from Cape Canaveral in Florida, OSIRIS-REx has begun its two-year journey to the asteroid Bennu, 7.2 billion kilometres from Earth.

The craft, measuring 2.4 by 2.4 metres, will arrive at Bennu in August 2018. Less than two years later, it will use a robotic arm to grab a chunk of the asteroid, anywhere from 60 grams to two kilograms in size. It will then leave the asteroid in March 2021, and return the space rock sample to Earth in September 2023.

It's a highly ambitious mission, with a huge number of unknowns. For example, this is only the second mission to try to return a sample from an asteroid. The first, Japan's Hayabusa spacecraft, ran into a number of complications following its launch in 2003, including the process of actually collecting the sample, and only just managed to limp home with a tiny selection of rocky grains on board in 2010.

Scientists will be hoping for a better turn of events this time around, with the aim of furthering our understanding of asteroids – and also perhaps preventing a deadly impact with Earth in the future.

On board OSIRIS-REx

What instruments will the spacecraft use to study Bennu?

GN&C LIDAR

This system, standing for Guidance, Navigation and Control, will help measure the range to Bennu during sample acquisition.

Mission goals

The main goal of the OSIRIS-REx mission is to return a sizeable sample to Earth for study, letting us see what asteroids like Bennu are made of, where they came from, and what role they had in the early Solar System. It's possible that asteroids like Bennu brought water to Earth, and possibly the ingredients for life, too.

Bennu also has a very small chance of hitting Earth in the late 22nd century, rated at one in 2,500. Scientists will study the effect of the Sun on the asteroid, known as the Yarkovsky effect, to see if this might push it more into our path in the future and raise the chance of it hitting us.



No one is quite sure what Bennu looks like yet

TAGCAMS

Additional cameras, known as the Touch-And-Go Camera System (TAGCAMS), are able to snap extra images of the sample capture event.

Mission timeline

How OSIRIS-REx will travel to Bennu and return to Earth



1. Launch 8 SEPTEMBER 2016

OSIRIS-REx successfully launched atop an Atlas V rocket from Cape Canaveral in Florida, and started its two-year journey to Bennu.

"OSIRIS-REx will return the largest extraterrestrial sample to Earth since the Apollo missions"



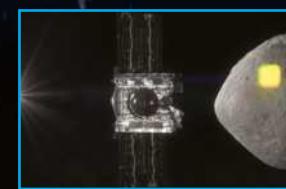
2. Gravity assist 23 SEPTEMBER 2017

OSIRIS-REx swung back past Earth after a year orbiting the Sun, giving it a boost from Earth's gravitational field towards Bennu.



3. Approach AUGUST 2018

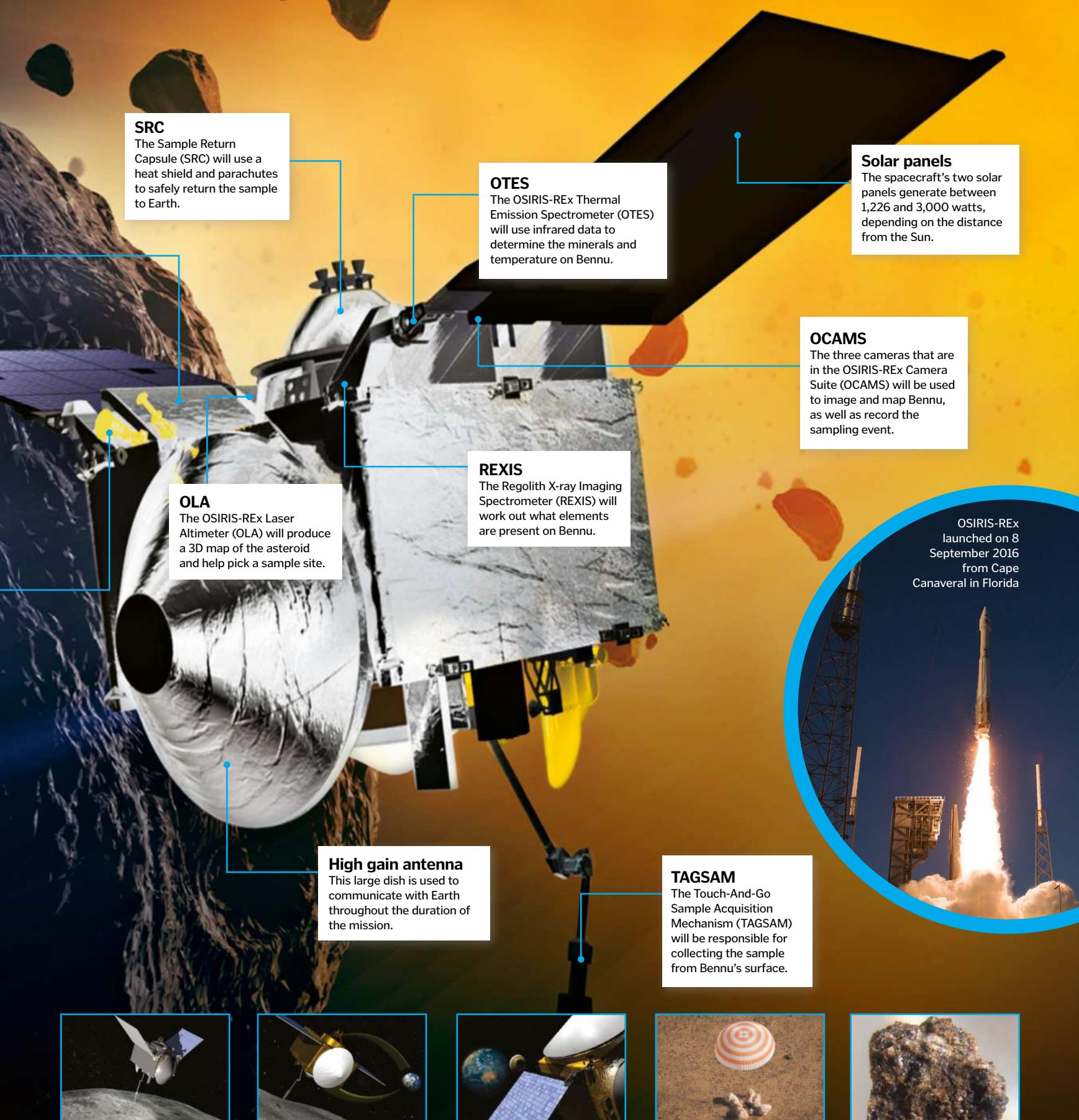
The spacecraft will officially begin its approach to Bennu when it is 2 million kilometres away, by matching the asteroid's speed.



4. Survey DECEMBER 2018

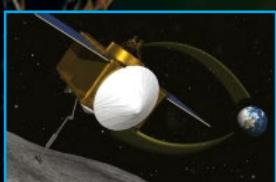
OSIRIS-REx entered orbit and started a survey of the asteroid, where it will find a suitable site to collect a sample from to bring back.

DID YOU KNOW? The last US spacecraft to return a sample to Earth was Genesis in 2004, which returned particles of solar wind



5. Sample collection MARCH 2021

OSIRIS-REx will hover a few metres away from Bennu, extend a robotic arm, and fire three bursts of nitrogen gas to collect a sample.



6. Return MARCH 2021

With the sample safely stowed in a capsule, OSIRIS-REx will now begin its journey back to Earth. It will have a long way to go.



7. Ejection 24 SEPTEMBER 2023

Four hours before re-entry, OSIRIS-REx will jettison its return capsule to journey alone. The spacecraft will be manoeuvred to orbit the Sun.



8. Landing 24 SEPTEMBER 2023

The capsule will free-fall before deploying a parachute at an altitude of 3,000m, bringing it to a soft landing in the Utah desert.



9. Research BEYOND SEPTEMBER 2023

Scientists will open the capsule, and study samples for organic compounds and clues to our own beginnings.



Inside Spaceport America

In the town of Truth Or Consequences is the world's first commercial spaceport

Spaceport America is described as the world's "first purpose-built commercial spaceport". It is an impressive 10,000-square-metre terminal building with a 3,657-metre runway, nestled in the remote Jornada del Muerto desert basin in New Mexico, US. Its ambitious organisation is on a mission "to make space travel as accessible to all as air travel is today".

The \$200 million facility was designed by UK-based Foster and Partners, and funded by New Mexico state taxpayers. It was built to mirror the spacecraft that it will one day house, with a curved outline, skylights, and a three-storey glass front looking out over the taxiway.



The airport's hangar is known as the Gateway to Space building

The structure sinks down into the ground to maximise energy efficiency, and winds whistle through to control the temperature inside. Like a standard airport, it has hangars and a departure lounge, but it is also fitted out with a control room, space for astronauts to don their suits, and training facilities for flight preparations to be carried out.

The spaceport officially opened in 2011, with Virgin Galactic signing a 20-year agreement as the primary tenants back in 2008. However, it has been a slow start for this ground-breaking project. Virgin Galactic plans to use the facility to take passengers into space onboard SpaceShipTwo, but after a tragic fatal accident in 2014, the project is now running several years behind schedule.

A number of smaller private companies have paid to use the facilities and over 20 launches have been made, but this is far fewer than originally expected, and the building is losing money. Time will tell whether Spaceport America will achieve its dream of becoming a bustling hub for commercial space travel. For now, it seems that while the building is ready, the spacecraft aren't quite prepared for take-off.

Catching a spaceplane

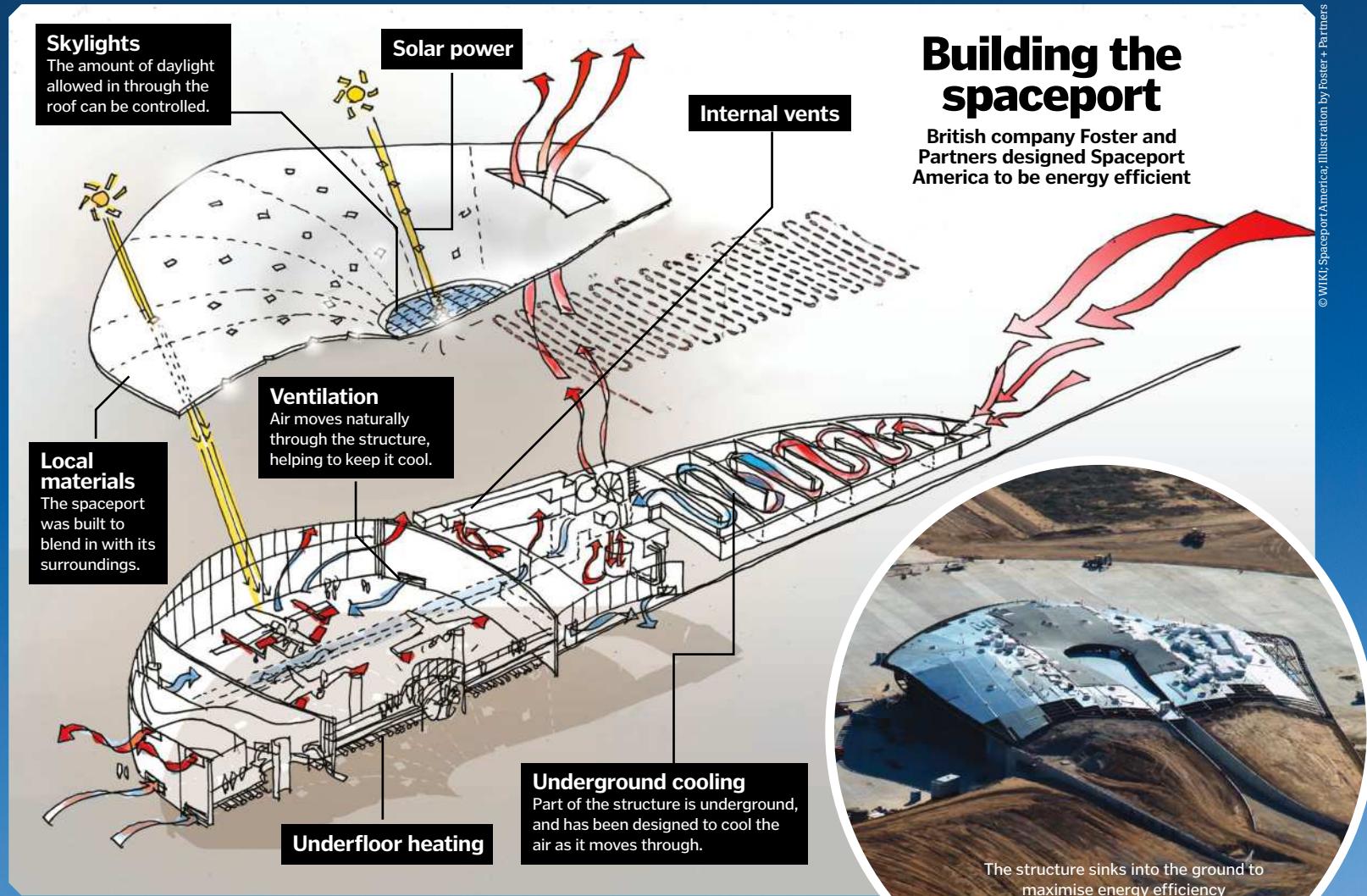
In the future, it is hoped that Spaceport America will be the top destination for tourists looking to catch a glimpse of the world from outer space. Virgin Galactic intends to prep their would-be astronauts with an intense three-day training course on site. Health and safety is a priority, with emergency response taking the number one spot on their planned training protocol. Medics will also be on hand, to ensure that passengers are physically and mentally ready for the intense experience of the space environment. They will be exposed to g-forces in simulators and light aircraft in preparation for the big day. Once the trip is over, SpaceShipTwo will land on the runway like an airplane, and the passengers will be able to celebrate in style back at the spaceport.



Virgin Galactic's WhiteKnightTwo will help launch SpaceShipTwo into space



The runway is almost 4km long



Building the spaceport

British company Foster and Partners designed Spaceport America to be energy efficient

© WIKI, Spaceport America, illustration by Foster + Partners

Kodiak Launch Complex

Spaceports of America

Oklahoma Air and Space Port

Mojave Air and Space Port

Cecil Field Spaceport

California Spaceport

Cape Canaveral



"Like a standard airport, the spaceport has hangars and a departure lounge"



REMOTE-CONTROLLED EXPLORERS

How robot avatars could take us to exciting new worlds without us having to leave Earth

Telerobotics might sound like something out of science fiction, but chances are you have had quite a lot of interactions with it. Have you ever driven a remote-controlled car, used virtual reality, or heard about a spacecraft docking with the International Space Station (ISS)? Then you've probably got a good idea of what telerobotics is.

This is the idea that robots can be operated remotely by humans in another location, and on Earth there are many uses for telerobotics. We send submersibles into our oceans (that are controlled by humans on land) to explore parts of the ocean that are difficult for humans to reach. We also use them to explore areas high in radiation, such as Japan's Fukushima reactor, which would be deadly for humans to explore. We're even starting to use remote surgery,

known as telesurgery, to allow doctors to operate on patients they can't reach.

When it comes to space travel, there are a range of interesting ways that telerobotics could be used in the future and many that are being used already. This includes enabling astronauts to operate machinery on Earth, perform activities in space without venturing outside or even exploring strange new worlds. Astronauts have been busy practising how to control rovers on Earth from the ISS, using controls on the station to move and operate robotic arms and other instruments.

This includes the German Aerospace Center's (DLR) Rollin' Justin humanoid robot, which has movable limbs and hands that astronauts can control from orbit, and cameras so the astronauts can see what the robot is doing. In 2017, it was

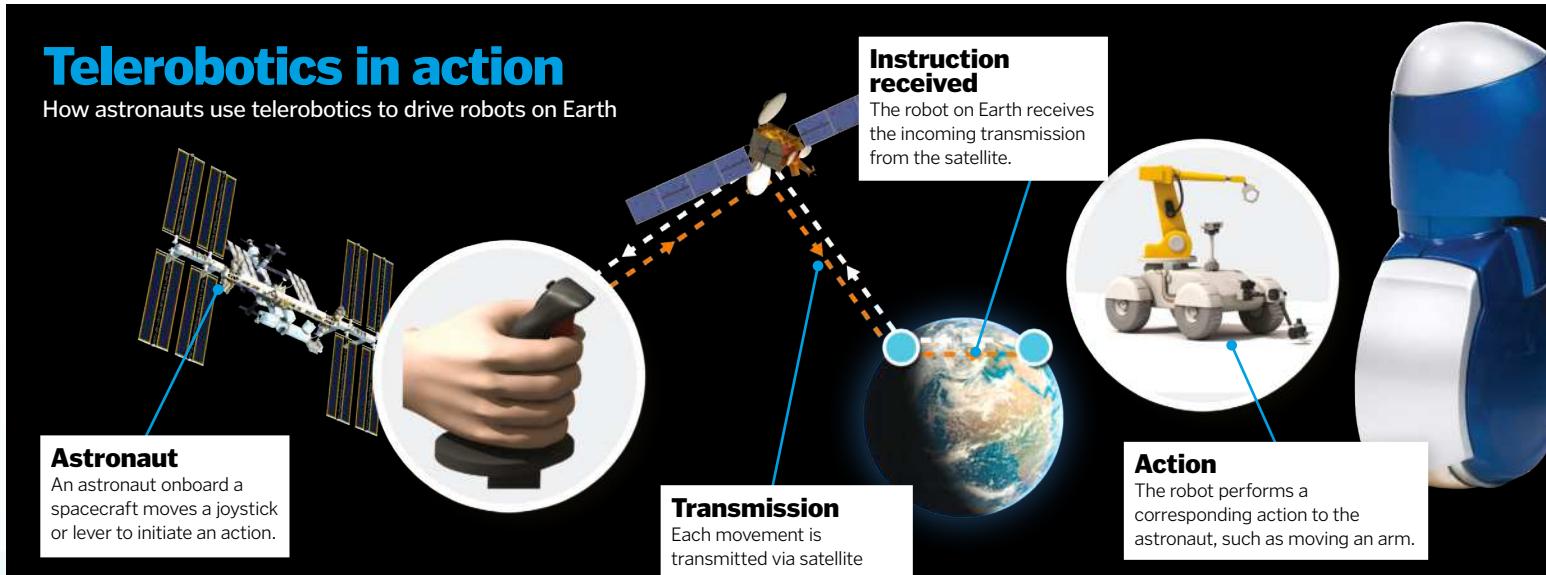
controlled on Earth by European Space Agency (ESA) astronaut Paolo Nespoli in space. In 2015, NASA astronaut Terry Virts 'shook hands' with a telerobotics specialist back on Earth. Virts was using a joystick on the ISS, with another on Earth mimicking his actions. Using haptic feedback, Virts was able to 'feel' a handshake from the operator on our home planet, the first ever handshake between space and Earth.

The idea is that in future these techniques could enable more rapid and easier exploration of other worlds like Mars. We have sent several rovers to Mars, all of which are controlled from Earth. Engineers input commands for the rover to carry out, and the rover then acts out those



Telerobotics in action

How astronauts use telerobotics to drive robots on Earth





The Rollin' Justin robot's wacky limbs make it easier to control



The Avatar X Lab in Kyushu, Japan, will be used for lunar experiments, with the location chosen for its resemblance to the Moon's surface

"There are a range of ways telerobotics could be used in future"

commands. But it takes an average of 14 minutes for a command to reach the Red Planet, making progress slow.

Rovers have typically only been able to travel up to tens of metres per day or perform simple tasks like scooping up material from the surface. In the future, however, we may well have astronauts in orbit around Mars. While we might one day also set foot on the Red Planet, there are many unknowns before that can happen. But astronauts orbiting Mars could operate robots on the surface almost in real time, enabling much more complex missions that can accomplish a lot more than those that are controlled from Earth. This form of telerobotics also eliminates the human risk factor. Mars is a dangerous place, but if the astronauts can remain safely in orbit then we may be able to study Mars in detail much sooner than if we had to wait until we could send humans to the surface.

Before Mars, it is likely these techniques will also be used to explore the Moon. NASA and its international partners are currently developing a space station that could orbit near the Moon in the coming decade called the Deep Space Gateway (DSG), in which astronauts could live

5 FACTS ABOUT TELEROBOTICS PROS AND CONS

1 Remote operations

Telerobotics enables astronauts to operate a machine from afar without travelling there themselves, which could be very useful on places like Mars.

2 Lower risk

Without the need to travel to potentially dangerous environments, remaining in the safety of a spacecraft can reduce the risk to human life.

3 Quicker missions

Telerobotics could make missions to other worlds more feasible in a shorter timeframe, as we won't need to develop the technology to land humans.

4 Time delay

It does still take some time for the signal to travel to the robot, which means that actions are not performed in completely real time.

5 Line of sight

When an astronaut loses sight of a robot, such as when they orbit to the other side of a planet, they will lose control of it.



and work just like on the ISS. These astronauts could control a number of robots on the Moon, such as rovers to build habitats that they can live in for long periods of time or machines that can explore the dark but fascinating craters of the Moon that would be dangerous for humans to venture into.

Looking far into the future, some even more exciting possibilities start to spring up. Worlds like Jupiter's icy moon Europa and Saturn's equally frosty moon Enceladus may have life-harbouring oceans hiding beneath their surface. But being locked beneath tens of kilometres of ice, the chances of humans exploring these places seem slim at best. What if instead, a robotic submarine (one controlled by humans on Earth or perhaps even orbiting nearby in space) could melt its way through the surface of one of these moons before swimming through the watery depths below?

There are still issues to iron out with telerobotics. One is that astronauts need to be in sight of any robot they are operating. If they are not, such as when they are orbiting on the other side of the Moon to a robot on the surface, they will not be able to communicate unless a relay satellite is used to bounce their signal off. Another is the amount of bandwidth available, and therefore the amount of data that can be sent to the rover, which could limit activities. Further still, while the time delay is reduced by having astronauts nearby, it is not eliminated, and even a slight lag of a few seconds can cause problems if a robot gets into a sticky situation.

Even so, there's little doubt that the future of telerobotics could be thrilling. By enabling more rapid exploration of other worlds, it could give us a way to explore interesting locales without having to risk the lives of humans. Who knows, maybe one day an astronaut will get to drive a remote-controlled car on Mars, just like they once did on Earth.



An ESA member of staff gets to grips with a telerobotic exoskeleton

EARTH

The Moon and beyond

How telerobotics is used now and what it could do in the future

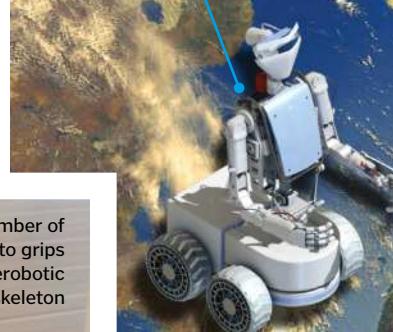
Astronomy

Many telescopes – situated in remote locations – are operated remotely by astronomers.



Every-day use

Using a remote-controlled drone or car on Earth is a type of telerobotics.

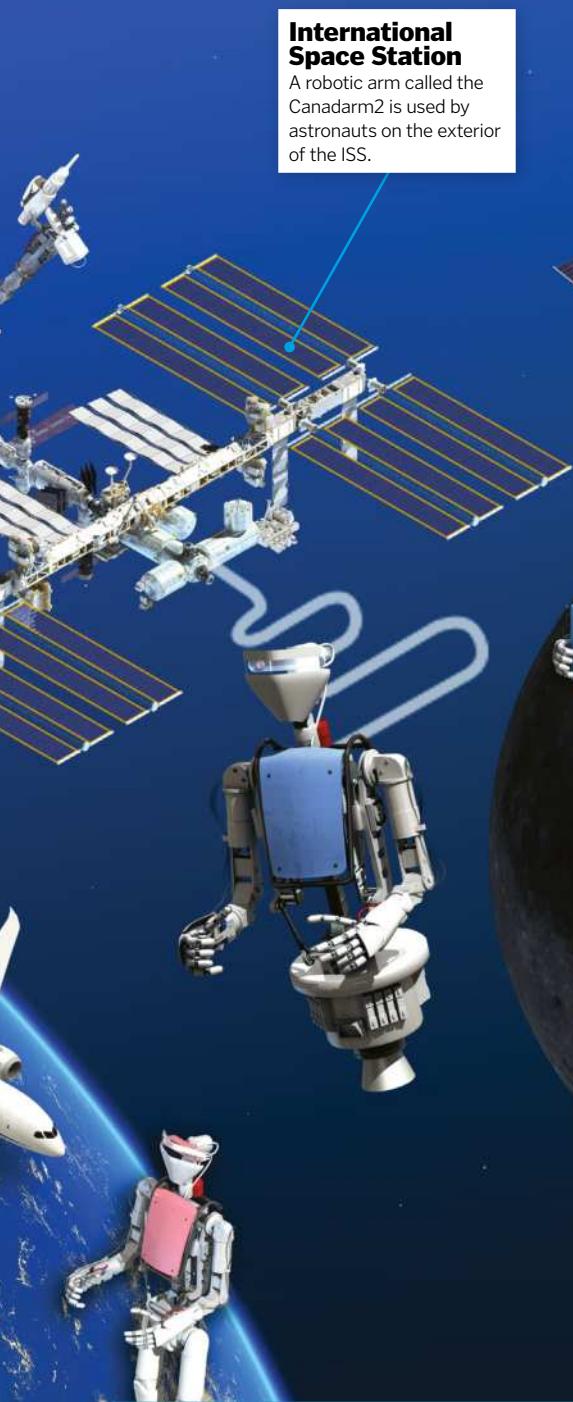


"The future of telerobotics could be thrilling"

Dangerous environments

Robots can be operated remotely on Earth to travel to the bottom of oceans or investigate radioactive zones.

LOW EARTH ORBIT



International Space Station

A robotic arm called the Canadarm2 is used by astronauts on the exterior of the ISS.

MOON, MARS & BEYOND



Lunar construction

Future telerobotics missions could involve using robots from afar to build on the Moon.

Beyond Mars

Other worlds like Jupiter's moon Europa could also be explored using telerobotics from far away in the future.

Mars

Before humans set foot on Mars, they may control robots on its surface from Martian orbit.

Moon exploration

Using telerobotics it's possible to explore the Moon with a rover with just a few seconds delay.

The K10 rover was controlled on Earth by astronauts on the ISS



Space rover

In 2013, NASA astronaut Chris Cassidy and ESA astronaut Luca Parmitano both successfully operated a rover at NASA's Ames Research Center in California from the ISS. This was the first time a robot on Earth had been completely controlled by astronauts in space. The four-wheeled robot, called K10, was equipped with a scanning laser system and multiple cameras so that the astronauts could see what they were

doing, letting them drive across the ground and complete tasks. Cassidy successfully used the rover to navigate rocky Moon-like terrain, while Parmitano used the rover to deploy an antenna, something that might need to be done on a real lunar mission one day in the future. The project was seen as being a key test in proving that astronauts could operate rovers on the surface of another world.



Growing food on Mars and the Moon could hugely benefit plans to colonise other worlds

Farming on alien planets

Mars and the Moon could be new places to grow food

Believe it or not, the soil found on the Moon and Mars could actually be much more fertile than some of the dirt found on Earth. If we are ever to go on to colonise other worlds – with the Red Planet being our number-one target – then this is very good news for astronauts.

It's thanks to a team of scientists in the Netherlands, who have braved volcanoes in

Hawaii and Arizona to obtain material akin to Martian dirt and lunar soil, to provide us with the information that could help humans one day settle on an alien planet. Both soils have the essential ingredients plants need to grow – nitrates and ammonium.

The experts found – by using 'fake' minerals from Mars and the Moon to try and grow carrots, tomatoes, weeds and wheat – that

untreated soil found on Mars was the plant's favourite. On the other hand, Moon dirt didn't agree with them completely, with some crops struggling to grow.

All's not lost for crop farming on the Moon, though – scientists think that pumping our natural satellite's soil with nitrogen-fixing bacteria could be the ticket for growing crops on our cratered companion.

Rockets of the past, present and future

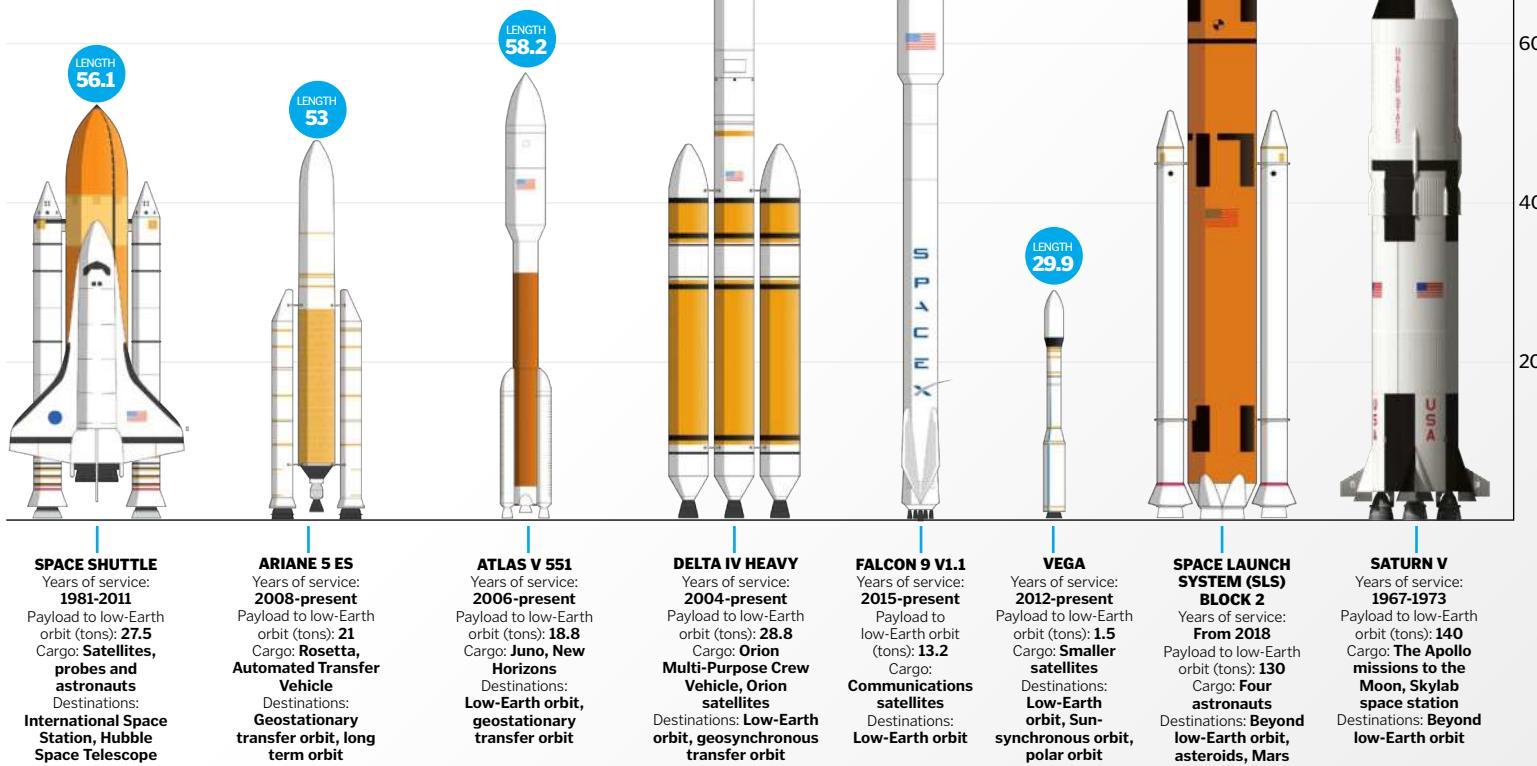
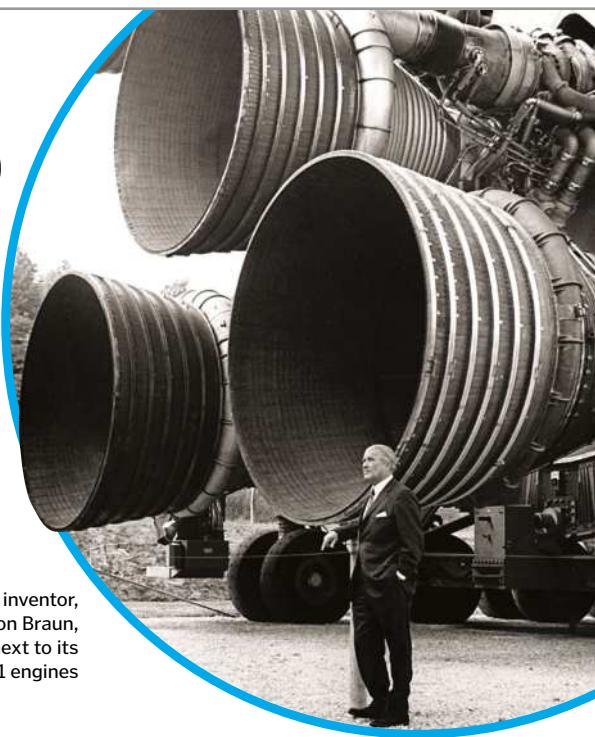
How does NASA's Space Launch System compare with some of history's greatest launchers?

Ever since the words "One small step for man, one giant leap for mankind" echoed from our television sets, space



exploration has been pushed to be faster, stronger, and bigger. This can be seen in the wide array of rockets that have been developed over time. While the smallest rocket of all time, the Space Shuttle, has been in use since 1981, the largest rocket has never been put to use at all. The At 111 metres, the Space Launch System (SLS) Block 2 is set to be used in 2018, and will carry human astronauts. That doesn't mean that big automatically equals modern; the Saturn V almost matches the SLS, despite being around 50 years old.

The Saturn V's inventor, Wernher von Braun, stands next to its gigantic F-1 engines





LIVING *ON THE* MOON

How we could turn craters into colonies for human life

The Moon is our closest neighbour, but only 12 people have ever set foot on its surface. Since 1972, the only visitors have been robots, orbiters and probes. For a long time there was little interest in going back, but at just three days journey away from Earth, the Moon is an obvious target for further investigation. With more countries establishing their own space programmes, and an increasing number of private companies entering the field, interest in the Moon is growing once again.

The environment on the Moon's surface is hazardous, but if we can find a way to construct a base we would gain access to a wealth of off-world resources. It is a prime location for telescopes and communications equipment,

and its unique environment could hold clues to the history of the Solar System. The Moon's potential has been recognised by organisations across the world, and there are now several exploratory missions in development. At the moment, these are focused around finding out more about the Moon's potential, but over the next few decades, manned missions and even base construction could be on the agenda.

Russia's Roscosmos are planning a series of Luna-Glob missions as a starting point for establishing a robotic base, and in collaboration with the European Space Agency, they are hoping to scope out the Moon's south pole in 2019 and 2020. The China National Space Administration are developing a series of Chang'e probes to collect lunar samples in

preparation for future mining missions, and they are building a shuttle capable of lifting human astronauts to the Moon. What's more, in 2007, Google launched the Lunar XPRIZE, encouraging private companies to land rovers on the satellite's surface. Even NASA, who has chosen to focus their resources on manned missions to asteroids and to Mars, are developing a probe to map the water deposits on the lunar south pole.

At the moment, we are just taking our first tentative steps towards further exploration of the Moon, but in the future a science fiction-style base on the surface could become a reality. We explore what such a lunar outpost might look like, and what hazards and challenges could get in the way.

Why the Moon?

With preparations already underway for manned missions to Mars, some might question the logic behind a return to the Moon, but a lunar outpost could bring several advantages. A trip to the Moon and back could be completed in under a week, and the surface is rich in resources. Lunar dust contains hydrogen, oxygen, iron and other metals, and if these resources could be mined, it could provide a close off-world source of water and building materials.

The far side of the Moon is shielded from the noise of Earth's communications, providing a quiet vantage point for looking out into the universe, and the near side has a constant view of the surface of our planet, making it an ideal place to set up monitoring stations. Navigational support could also be provided for a variety of operations, from search and rescue on Earth to deep space exploration.

A base on the Moon would also allow us to look closer at its geology, which in turn would help us uncover more about its history and the evolution of the Solar System. Experiments could be conducted, and materials and equipment could be tested, away from the familiar conditions on Earth.

Lunar holidays

With space tourism barely in its infancy, it might seem a bit premature to consider the idea of holidaying on the Moon, but if humanity were to establish a base up there, visitors would almost be inevitable. The company Space Adventures has already sold two \$150 million tickets for a trip to visit the Moon in 2018, and more private organisations are looking to set up their own tours. Rules set out in the 1967 Outer Space Treaty state that the Moon cannot be claimed by any country, even if they have set up a base there. However, laws regarding the exploitation of the Moon and its resources for commercial gain have not yet been fully established.

A base on the Moon could pave the way for a new kind of holiday



Colonising space

A lunar base could perform many different functions, from mining to communications

Stepping stone

Establishing a base on the Moon would be a big step towards colonising Mars.

Mining and excavation

The Moon is rich in resources and could be used for construction or to make fuel, oxygen and water.

Space outpost

The Moon's location and lack of atmosphere make it a good place for communications equipment and sensitive telescopes.

Exploration

Large vehicles could be used to carry explorers away from established bases to explore the Moon.

Refuelling

The low gravity on the surface would allow spacecraft to land, refuel and take off much more efficiently than on Earth.

Technical testing

Building a protective habitat on the surface of the Moon will test technologies to their limits.

How to build a base

The Moon has little atmosphere and none of the protective shielding that we enjoy here on Earth; as a result, the surface is hostile. It is pummelled by solar winds, scorched by radiation, and chunks of rock regularly fall from the sky. The ground is coated in the shattered remains of ancient asteroid impacts, forming a thick layer of sticky dust, and with no atmosphere or weather to wear the particles down, the grains are razor sharp. A successful base would need protection against all of these threats, and, for people to stay there long-term, it would also require a steady supply of food, water, oxygen, power, shelter and rocket fuel.

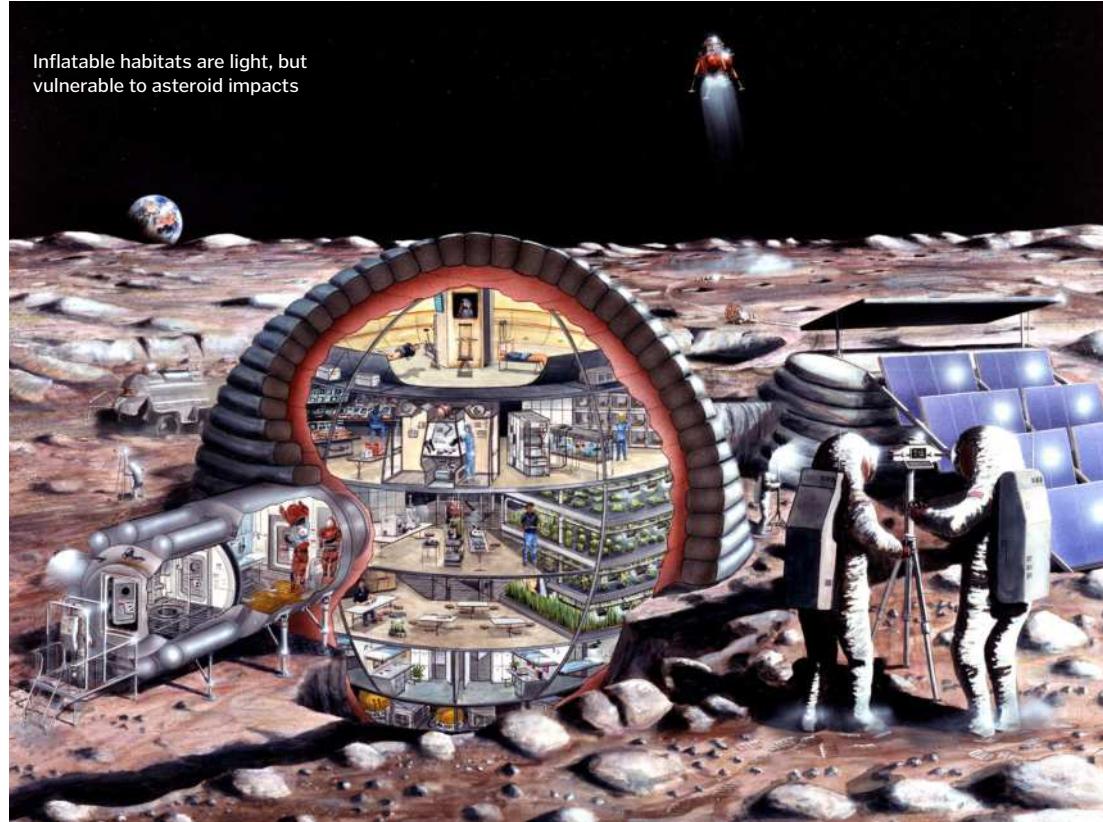
One of the most popular concepts for a lunar base is inflatable housing – lightweight and easily assembled by pressurising from the inside. With the airlock from the landing capsule used as a door, these structures could provide a quick and simple solution to setting up a base. However, a puncture could prove catastrophic, so the pods would need to be shielded in underground chambers or beneath piles of Moon dust.

Flat-packed panels could also be shipped in from Earth to build sturdier dome or hangar structures, but it would be much more fuel-efficient to use building materials found on the surface of the Moon. When heated, lunar dust can be transformed into a tough solid that could be used to construct buildings and roads, and 3D printers could one day be used to make structures from the regolith.

In the right location, solar panels could provide renewable power for the base, and, if plants are able to grow on the Moon, it could one day be possible to set up a semi-sustainable farming and composting system. Then, if water, oxygen and hydrogen (rocket fuel) could be extracted from lunar dust, a base might even be able to become self-sufficient.

Unfortunately, there are still major challenges to be overcome before we reach this stage, not least the devastating effects of lunar dust. The dust seems to find its way inside even tightly sealed spaces, causing rapid damage to equipment. There are some ideas to get around this, including cable cars or covered transport tubes to minimise the disturbance on the surface, and clean rooms and air locks to keep inside spaces dust-free.

"Solar panels could provide renewable power for the base"



Craters

Craters near the poles could provide protection against solar wind.



Smooth terrain

The surface near the equator might be easier to land on, but the temperatures here vary by hundreds of degrees.

WHERE TO BUILD?

Choosing the right spot could mean the difference between success and failure

NEAR SIDE

FAR SIDE

Sunlight

The equator is in darkness for 14 days at a time, but some places near the poles are in near constant sunlight.

Location, location, location

The Apollo missions landed close to the Moon's equator, where the surface is smooth and entering orbit is easy, but these regions have serious problems with temperature control. The Moon turns on its axis once every 28 Earth days, so daytime at the equator lasts for two weeks, and temperatures climb to more than 100 degrees Celsius. For the other two weeks, the same spot is plunged into total darkness and the surface cools to 150 degrees below freezing.

These wide fluctuations could pose real problems for buildings and equipment, and

with sunlight absent for days at a time, solar power would be intermittent. Facing head on to the Sun and with little in the way of atmosphere, the equator is also blasted by radiation and solar winds.

At the poles, night and day are less dramatic. The surface is rougher, but certain areas receive sunlight for most of the year, and the temperature remains more stable at around zero degrees Celsius. There is also water ice trapped at the poles, which could provide gases, fluids and even rocket fuel.

Permanent shade

The north pole is smoother than the south pole, but parts of it are in constant shadow.

Helium-3

Solar winds have left rich helium-3 deposits near the equator, providing a potential source of clean energy.

Lava tubes

Caverns beneath the surface of the Moon could provide shelter from radiation, space weather and temperature changes.

Water ice

There is frozen water locked away near to the Moon's north and south poles.

One promising location is Shackleton Crater, which is found at the Moon's southern pole. It receives sunlight for around 80 per cent of the year, which could provide a near constant source of electricity from solar panels. Building a base near the equator would be more challenging, but underground habitats could provide enough protection in more exposed locations. Lava tubes like the Marius Hills pit could offer ready-made shelter from temperature fluctuations, solar wind, radiation and surface dust.



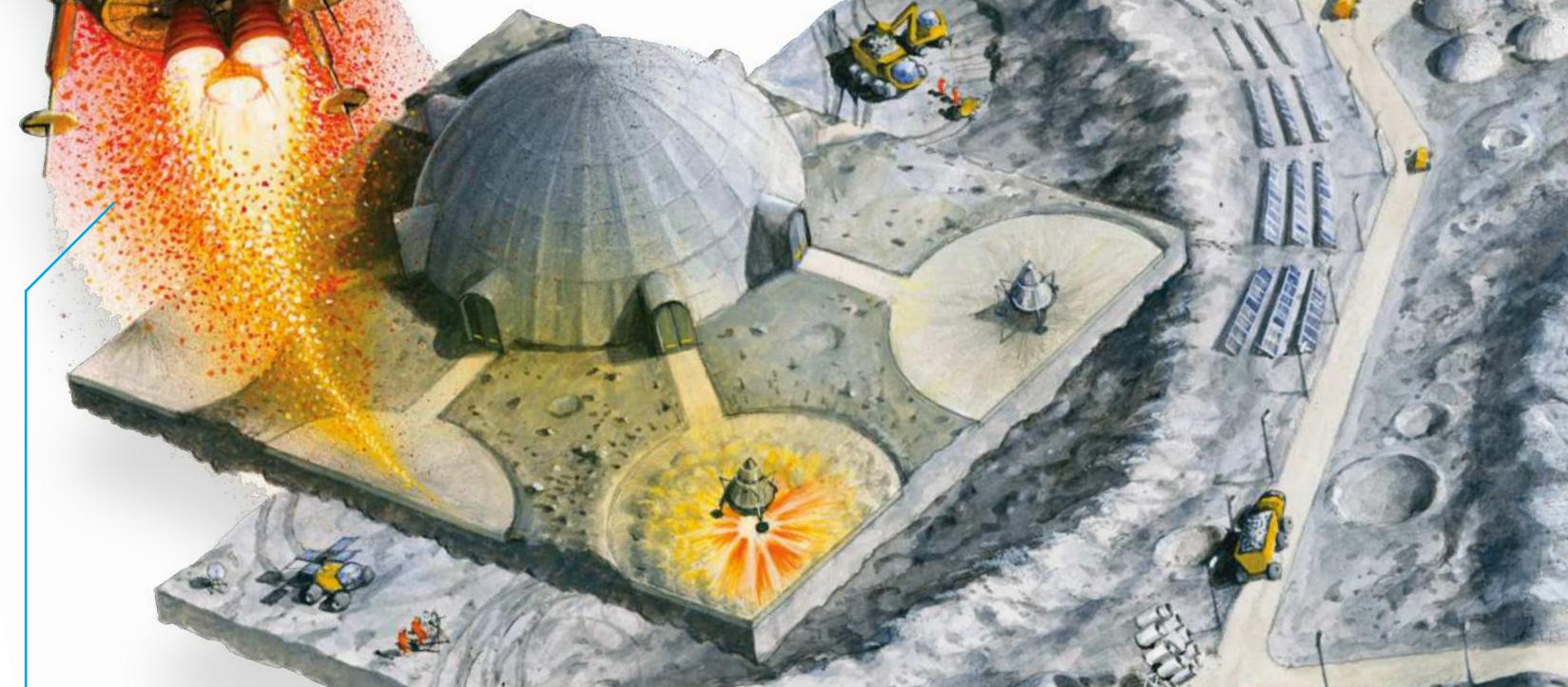
WHAT WOULD A LUNAR COLONY LOOK LIKE?

The Moon is not a safe place for humans; the base will be essential for survival

Inflatable habitats
Building materials are heavy, so one option is to use inflatables. These would need to be protected from impacts.

Water supply

Water could be extracted from lunar dust by heating it with hydrogen gas.



Launch and landing

The gravity on the Moon is low, so launching and landing spacecraft requires much less fuel than it does on Earth.

Telescopes and equipment

Away from the interference of Earth's atmosphere, a lunar base could house powerful telescopes.



Radiation shielding

Buildings would need to be protected from radiation. A popular idea is to bury them under layers of moon dust.

DID YOU KNOW? The Moon is an average distance of 384,400km away, equal to about 30 Earths lined up side by side

Oxygen

Water extracted from the lunar surface could be split into hydrogen and oxygen using a technique called electrolysis.

Glass roads

Microwaves could be used to melt the dust on the surface of the Moon to produce smooth, tough roads.

Food

Farming resources would need to be transported to the Moon, but waste could then be recycled to keep plants growing.

Flatpack buildings

Buildings could be constructed using geometric frameworks shipped in pieces from Earth.

"Only a handful of people have visited the Moon's surface, and the longest stay lasted three days"

Home away from home

Humans have been living in space since the 1970s, falling around the Earth inside orbiting space stations like Salyut, Almaz, Skylab, Mir and the International Space Station (ISS), but no one has been in orbit for longer than 438 days (the record set by Valery Polyakov), making the long-term success of space colonies hard to predict. Over 200 astronauts and cosmonauts have lived on the ISS, and by monitoring them closely we have learnt a lot about the effects of microgravity on the human body, but the Moon is a different environment. Only a handful of people have visited the surface, and the longest stay lasted for only three days.

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The Moon has a sixth of the Earth's gravity, and comes with its own unique challenges. The dust that coats the surface could prove one of the most difficult problems to overcome. During the Apollo missions, the sharp particles found their way into equipment, through vacuum seals, and even inside spacesuits, irritating the eyes and lungs of the astronauts.

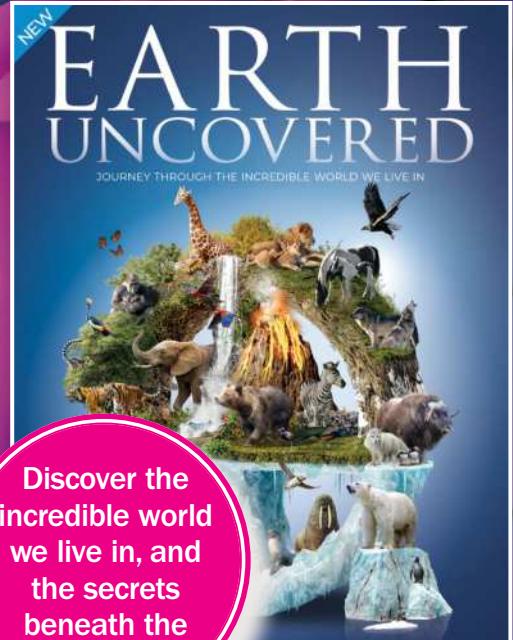
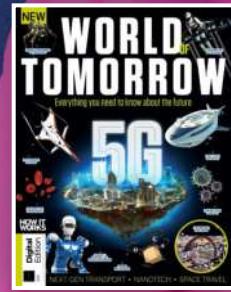
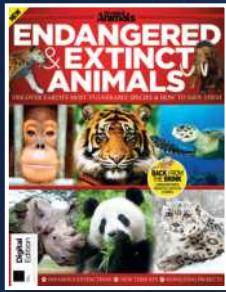
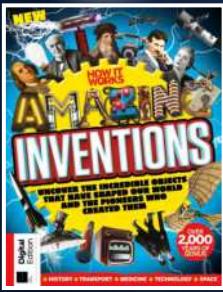
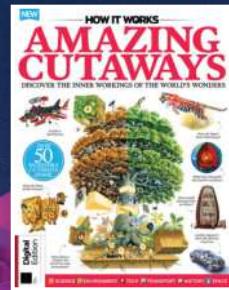
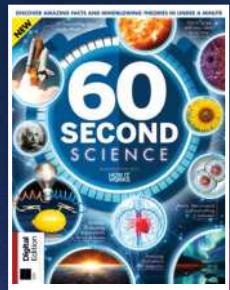
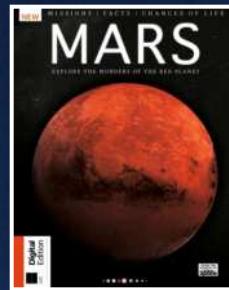
Permanent settlements on the Moon will only be possible with proper protection

Mining operations

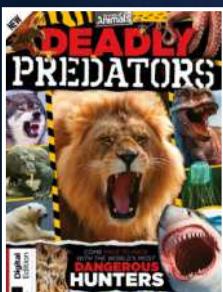
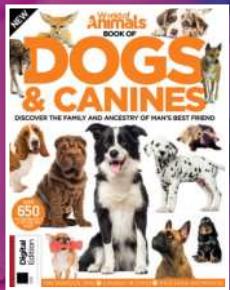
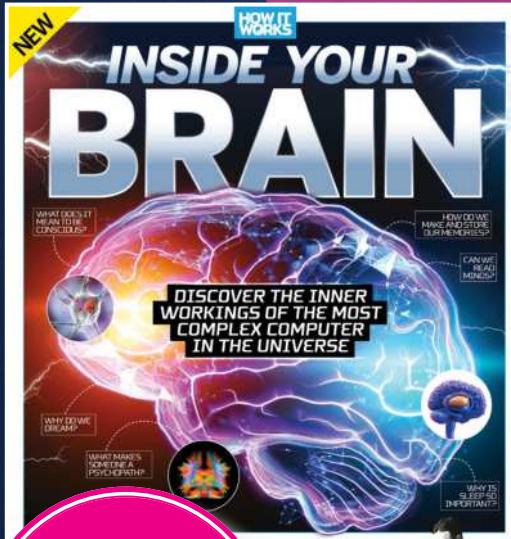
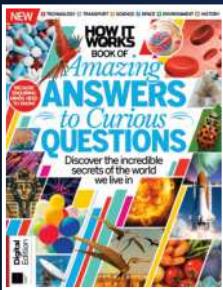
The dust – or regolith – could be mined for use as a building material, or to make oxygen, water and rocket fuel.



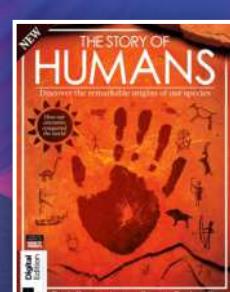
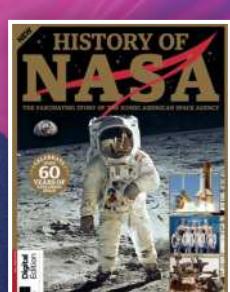
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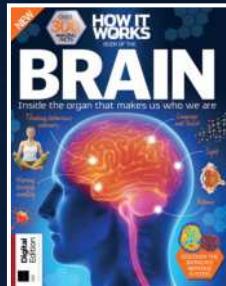
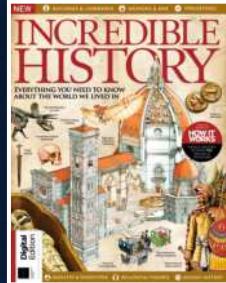
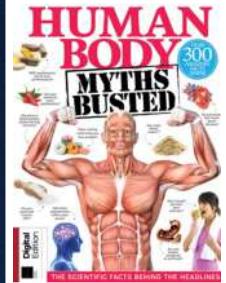
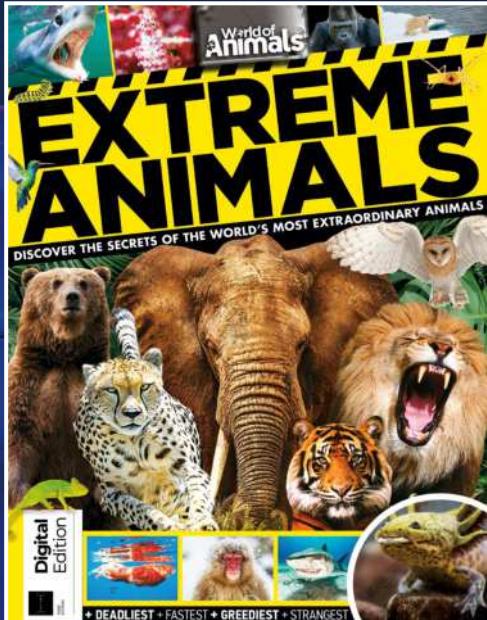
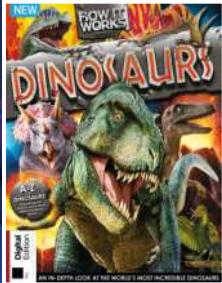
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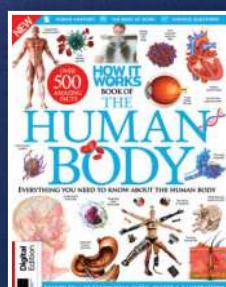
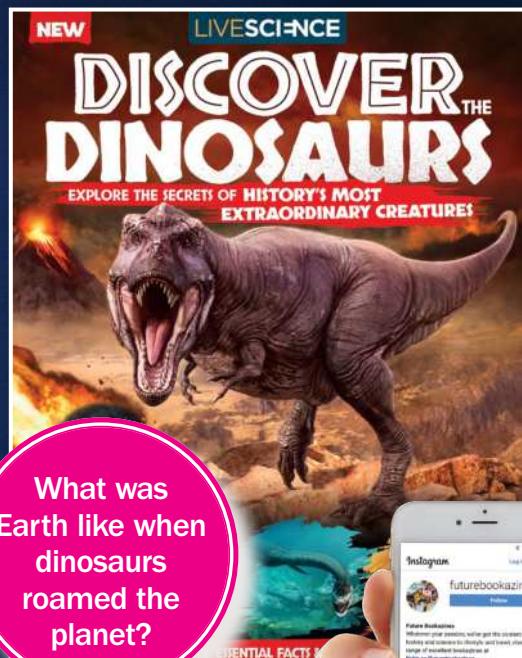
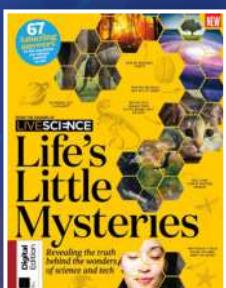
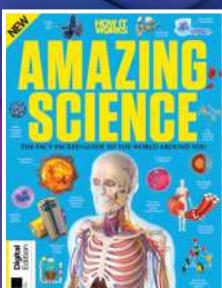


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A diagram of a test tube containing a yellow liquid with a small amount of green at the bottom, representing a sample.



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